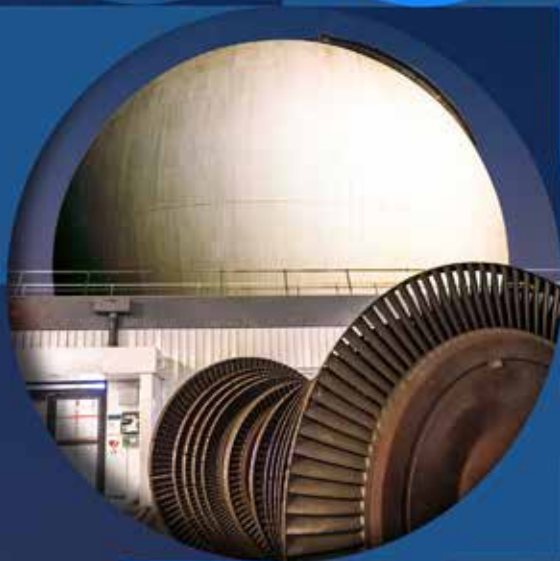


The Inspector General's report on Nuclear Safety and Radiation Protection

2024



FOREWORD



The French and British organisations are founded on the principle of the operator's primary responsibility for nuclear safety and radiation protection; the EDF Group's nuclear safety policy has legitimately made this an overriding priority.

Written for EDF's Chairman, this report gives my assessment of nuclear safety and radiation protection within the Group for 2024; it is the result of a collective team effort by Bertrand de L'Épinois, Jean-Baptiste Dutto, Paul Wolfenden and Bertrand Vauchy.

It has been compiled on the basis of thousands of workplace meetings with staff from all levels, representatives from trade unions, medical personnel, contract partners, local information commissions, and independent nuclear safety bodies, over approximately one hundred days of field visits. This year, the Chinese and Finnish operators also openly welcomed us to their sites.

This report is therefore also addressed to those, in France and the United Kingdom, who have enriched it with the quality and relevance of their observations, opinions, suggestions, and even their criticism. This proof of commitment and trust is a key factor in nuclear safety and is an obligation for us.

In keeping with the spirit of public awareness and transparency expressed in my appointment letter, this report focuses specifically on aspects that could negatively affect nuclear safety. It must stimulate reflection and lead to concrete action. It does make a number of suggestions for improvements, which concern not only the Group, but also its subsidiaries and contract partners. Its recommendations are validated and followed up by the Council for Nuclear Safety (CSN).

Changes to French and British energy policies, the increasing need for electricity to power our lives, and the massive arrival of new electricity producers will require us to adapt if we wish to guarantee a decarbonised and reliable energy mix. Collectively, we need to be aware that this obliges us to be more exemplary and rigorous and requires us to put our long-term efforts into meeting the challenges ahead.

For the first time in the history of the Games, the 2024 Olympic flame in Paris was illuminated in the air by the magic of electricity 'in a cloud of mist and light'. Raoul Dufy would have certainly immortalised this cauldron in his fresco! A magnificent illustration of the Group's capacity for innovation, taking advantage of this global event to promote the use of safe, controllable, carbon-free electricity produced by our power plants, even when the sun sets and the wind falls.

This document is available to the public in both French and English on the following sites: www.ignsnr.com et www.edf.fr.

**The Inspector General for Nuclear Safety
and Radiation Protection of the EDF Group**

**Admiral (Retd) Jean Casabianca
Paris, 15 January 2025**



Introduction
to the report

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Nuclear power offers a low-carbon response to economic development. International competition is increasing in both construction and innovation.

The EDF Group has a stable nuclear safety record, is improving its production, and exporting more than ever. The EPR at Flamanville 3 (FLA3) has been connected to the grid and Penly has started earthworks for a pair of EPR2^s. In the UK, the EPR project at Hinkley Point C (HPC) has begun mechanical, electrical and HVAC installation.

The industry is getting ready, but much remains to be done. Starting with a clear vision of our energy mix.

Cruas Meysse power station

Retrospective and perspectives

01

THE NUCLEAR SECTOR CONTINUES TO EARN INTERNATIONAL ACCLAIM

The year 2024 was quite similar to the previous year in a world resolutely marked by the renaissance of nuclear energy, which is recognised for its role in the fight against climate change. A few countries, notably European, are dampening this enthusiasm, displaying a reticence that is more dogmatic than rational, favouring an electricity mix still carbonised by imported gas.

A resurgence of new-build projects

Since 2000, worldwide nuclear power generation has stagnated at around 2,600 TWh, with the new reactors joining the grid only offsetting those having been shut down. Despite the increase in consumption, the share of nuclear power in the world's electricity mix continues to reduce. It is now below 10% but still represents 30% of decarbonised electricity and, when combined with hydroelectricity, 100% of decarbonised controllable electricity.

At the end of 2024, the world currently has 440 nuclear reactors in service, 60 under construction in 15 countries, 92 already planned and 343 proposed, with nearly half of these in China. Since 1 January 2024, several new nuclear reactors have been connected to the grid in the United Arab Emirates, China, India, the US and finally in France with FLA3, our 57th reactor in service. This promises significant growth in the global nuclear capacity, in line with the conclusions of the International Energy Agency's (IEA) 'Electricity 2024' report, albeit at a slower pace. This growth is being driven mainly by countries where consumption is rising sharply (China, India, etc.). In the Far East, for the past two years, Japan has been gradually restarting the power plants that were shut down after the 2011 Fukushima accident. The IEA estimates that the global electricity production as a whole should double by 2050.

The nuclear power revival in France after the Belfort announcement and authorisation to start the preparatory work on the Penly site are finding an echo in the UK and Belgium, as well as in Italy, Switzerland and Eastern Europe who are considering more nuclear power to meet their environmental objectives. Even in Germany, increasingly more people are questioning the policy of phasing out nuclear power.

What is more, competition is fierce. In addition to western GEN III technologies (AP 1000, EPR, APR 1400, etc.) there are competing technologies, either Russian for export (Turkey, Egypt, Belarus, Africa, etc.), or Chinese with the Hualong PWRs, essentially dedicated to the domestic market.

A wealth of feedback for the benefit of nuclear safety

After this overview of the future, it is important to highlight that, according to IAEA figures, the world's civil nuclear reactors in operation exceeded 20,000 reactor years in 2024. It is also the 70th anniversary of naval nuclear propulsion founded by Admiral Rickover, initiated on board the submarine USS Nautilus, which prefigured the commissioning of the first civil pressurised water reactor at Shippingport in the US in 1957, almost at the same time as the boiling water reactor at Vallecitos.



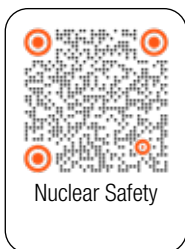
Technicians in front of the osmosis plant at Tricastin

This impressive accumulation of reactor operating hours provides a wealth of knowledge for operators thanks to the transparency of operating experience (OPEX) and exchanges. It is only relevant and interesting for nuclear safety if this feedback benefits everyone, particularly countries with smaller fleets. EDF, the world's leading operator, has opted for complete transparency in order to expand the shared database from which it can learn. As I have already mentioned in a previous report, nuclear safety is the overriding priority, and it is the role of national and international bodies to encourage cooperation and the exchange of information between operators, without prejudice to their nationality or diplomatic status. Safety must remain 'common property', as its failure remains a shared risk. Export control should not be used as a pretext for withholding information.

The US makes a comeback

The major noticeable change this year remains the US's return to the nuclear industry which, since the end of the 2000s, had turned massively to its shale gas stocks and renewable energies. The growing demand for electricity, the development of data centres (combined with their owner's desire for autonomy), as well as the recognition that nuclear power is a sustainable, controllable and low-carbon solution to meet these needs has favoured the relaunch of the sector (the project to restart one of the Three Mile Island (TMI) reactors). The Department of Energy (DOE) is providing undeniable support through a programme of guaranteed loans, subsidies and tax credits, despite the fact that the fuel industry is still dependent on Russia, which is exempt from sanctions in this area. Will the new administration make a U-turn in favour of fossil fuels?

A STABLE NUCLEAR SAFETY RECORD FOR THE GROUP, WITH IMPROVING PRODUCTION



In this Olympic year, our athletes performed in stadiums lit by low-carbon lighting provided by the EDF Group, which presents a safety record with real progress but some weaknesses, against a backdrop of a significant upturn in production.

2024: improvements and room for improvement

Although we must remain very humble when faced with figures that are far from revealing everything about safety and can change quickly, they are generally good in France and the UK. They show progress, compared with previous years, and over a longer time scale.

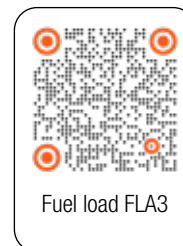
In France, the series of unplanned automatic reactor trips (UAT) in the second half of the year contrasts with the reduction observed in recent years. At nearly sixty per year in the early 2000s, the number of automatic reactor trips has dropped to around fifteen in recent

years. The year 2024 ended with a poor performance in France (29 UAT), unlike the UK, which is now down to a few. Almost half of them are caused by human and organisational factors. I can only endorse the action plan designed to boost the drive for rigour, skills development and management presence in the field. This approach complements the emphasis placed by the French Nuclear Generation Division (DPN) on leadership development and management of the professions, particularly in operations where it has been focused on process management. I note that Nuclear Operations and the Hinkley Point C (HPC) project are putting more effort into improving behaviours, and I appreciate the exchanges between our two fleets in this field.

In both fleets, alignment errors and isolation events, including administrative lockouts, remain a sensitive topic. Weak signals are the first warning sign that must prompt detection and prevention of more significant risks. Analysis of the TMI accident highlighted the crucial role of human factors. This requires sustained and coherent commitment from everyone involved, and the highest standards from management.

The particular case of EPRs

The FLA3 reactor is continuing its start-up. After fuel loading in May and going critical on 3 September, it was connected to the grid on 21 December 2024. Commissioning tests should be completed in the first half of 2025. Unsurprisingly, and without any real impact on nuclear safety, the number of start-up events is high and atypical. I appreciate the fact that the operator, with a good attitude to safety, is not hiding behind the complexity of the general operating rules (RGE) to justify all these events (*see Chapter 7*). FLA3 joins the three other EPRs, confirming the relevance of the concept and its performance. In China, with almost 13 TWh net, Taishan 2 beats the production record for a reactor in the space of a year. One year after it went into commercial production, Olkiluoto 3 is meeting 20% of Finland's electricity demand.



In the UK, after reviewing its schedule and cost, the HPC EPR project has begun its mechanical, electrical and HVAC (MEH) work. The type and intensity of activities are changing on a site that now employs more than 12,000 people of all nationalities. This phase is supported by a pragmatic campaign to raise awareness of health and safety rules in the workplace, with strong involvement from local management. I see this as a constant source of operating experience for future EPR2 projects.

Radiation protection and addiction: maintain the effort

For several years now, I have observed a tendency to trivialise radiation protection measures in France, which the DPN is striving to remedy. This calls for stronger support of the managerial efforts already being made (*see Chapter 3*).

In terms of addiction, the internal rules in France have been amended to include drug and alcohol testing. The aim on both sides of the Channel is to enforce prevention by proactively communicating and offering treatment for addictions that can in no way be considered as recreational in view of the nuclear safety principles that could be undermined. I note that systematic drug and alcohol testing is bearing fruit in the UK, particularly at HPC where the rate of positive cases is much lower than the national average. The Penly site should draw inspiration from this. I congratulate the management, local stakeholders, and staff representatives for working together to make progress in this area, vital for the health of our staff, the safety of our operational and engineering activities, and the reputation of our Group.



Teamwork in the Main Control Room, Dampierre-en-Burly

Recommendations followed by action

Reactivity management (2023 report)

I am very pleased with the way the DPN has handled this subject. The rules applicable in the control room have been reviewed, reducing the number of configurations at risk, and capitalising on the role of both the operators and control room supervisors in independent verification. This has resulted in a new version of the reactivity control guide.

This work on reactivity management must serve as a benchmark for the safety of all sensitive activities. I emphasise the importance of initial individual training in reactor physics and collective training to enhance the role of each person in a complementary way, a guarantee of safety. The relevance of our organisations, the lessons learnt from OPEX, and its assimilation by everyone, as well as humility and a questioning attitude can only benefit nuclear safety.

Support for sites in difficulty (2021 report)

In 2021, I focused on sites in difficulty, the importance of early detection and how to help them. Thanks to a renewed monitoring arrangement, the DPN is implementing support plans at a faster pace. They provide targeted support with better coordination. Now that the impact of the Covid pandemic and the corrosion stress cracking (SCC) issue is reducing, where the START 2025 plan is producing results, one observation remains valid: whatever actions are taken, the recovery of a site in difficulty can never be achieved if there is no collective ownership of the objective. As Andrew Carnegie said, *“A common goal, a shared vision and a strong, committed team are the keys to success”*.

The complexity and workload of the EDF France's industrial programme (fleet upgrade programme) adds to the challenge. Rationalising this programme and limiting modifications at the source remain essential (*see 2023 report*).

In the same spirit, Nuclear Operations has worked on their supervision system, with a more cross-functional analysis of the condition of their sites, better sharing between peers, earlier detection of warning signs of declining performance, and new support methods. Now that the service life extensions of the AGRs have been specified, Nuclear Operations can better plan investments and maintenance. I draw attention to the need for stronger human investment, especially as recruitment is continuing and we need to prepare the next generation for the transition from AGRs to EPRs, without overlap.

Loss of electrical supplies (2021 and 2023 reports)

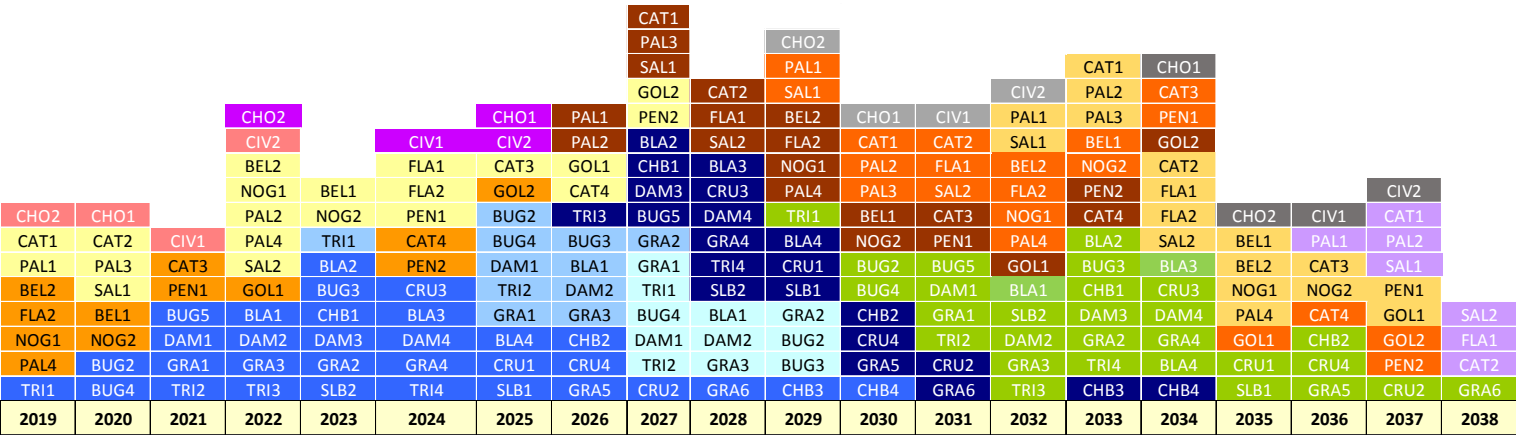
Lessons have been learned on both sides of the Channel from the loss of grid at a UK site in 2021. In the UK, equipment replacement, even though it is almost resolved, has taken too long and will be supported by modifications designed to increase the resilience of reactors with respect to their connection to the grid. The related safety studies have been expanded and interactions with grid operators have gained momentum. In France, action taken after a similar incident at Forsmark in 2006 has already made it possible to prevent the risk of propagation of overvoltage on the electrical distribution system.

In recent years, the multiplication of grid incidents has increased the constraints on the electricity system, including on the fleets. In view of these evolutions, grid ageing and increasing cyber threats, I believe that efforts must be continued in terms of skills and the management of degrading situations, as well as in terms of technical optimisation of the electrical protection settings in the UK (see 2023 report).

An excessively heavy industrial programme

In France, the ten-yearly outage programme is being met, despite the density of work and disruptions due to issues. Of the thirty-two 900 MWe reactors, 19 have already completed their 10-yearly outage programmes. This is a sign that our industrial programme is being maintained.

However, this programme is pushing the sites to the limits of their capacity, with a ten-yearly procession of work without any periods of respite. An additional risk factor is the disparity of reactor configurations on the same site, which calls for sustained attention, constant questioning and major investment from those working in the field. Tricastin, Bugey and Dampierre are the first to have reached VD4 status for all their reactors. They have four years left to prepare for their fifth ten-yearly outages (VD5) while completing phases B and B-plus of the previous outages. The diagram below clearly illustrates the complexity of the industrial programme for the French fleet, as well as the human and financial investment it entails. The VD5s must not place the sites in an uninterrupted cycle of heavy work once again.



Industrial Programme: Ten-yearly outages

Production is progressing despite load-following

In the end, production exceeded targets, which reflects progress in industrial management and illustrates that safety and production performance go hand in hand.

Having reached a low limit of 280 TWh in 2022 before increasing by 40 TWh in 2023, this year French nuclear power generation has returned to the levels prior to the stress corrosion cracking issue, close to 362 TWh.

With more than 89 TWh of electricity exported, the French system has beaten a record unmatched for more than 20 years (77 TWh in 2002) and achieving an all-time low in CO2 emissions. France will have supplied its neighbours, including Germany, with some of the cheapest and most decarbonised electricity in Europe (eight times less than the country of *Energiewende*). The improved availability of our production sources alone cannot explain this positive balance. Beyond the cultural shift to energy consumption moderation, the reduction of French consumption unfortunately illustrates the difficulties facing our industry.

In the UK, after two years of production significantly above target, Nuclear Operations had to readjust its target from 38 to 37 TWh in 2024. This was due to the event at Heysham 1 and the precautionary shutdown of its two reactors and the two identical reactors at Hartlepool. The impact of this generic incident was minimised by maintaining fleet maintenance and refuelling outage schedules.

SOVEREIGNTY AND PREPARATION FOR THE FUTURE

Investment in the fuel cycle

EDF's centralised storage pool project at La Hague is making way for a future complex that will be built by Orano, comprising three spent fuel storage pools to replace the existing pools.

The operation of the downstream plants (UP2-800 and UP3 at La Hague, Melox at Marcoule) is improving, which is gradually increasing the supply of MOX fuel to the EDF fleet and mitigating the risk of exhausting the capacity of the storage pools. Good management of the plutonium cycle strengthens our sovereignty (*see 2023 report*).

Shared between Orano, the CEA and the French government, the strategy for the downstream fuel cycle will shape the coming decades: major refurbishment and extension of current fuel cycle plants, new plants (Melox2, UP4, ADEC, conversion of reprocessed uranium), and preparation for GEN IV reactors (*see below*).

New nuclear ambitions

Ambition 2035

EDF's project called 'Ambition 2035', the year the first EPR2 is scheduled to go online, sets the target to build a reactor in 70 months. To achieve this, the nuclear sector needs to prepare itself for the battle (*see Chapter 8*). The *Banque Publique d'Investissement* is supporting companies in the sector to improve their productivity. The Group has acquired the GE factories where the ARABELLE turbines are built and sensitive companies such as Jeumont Electrique and the valve maker Vanatome. The incorporation of these new companies so they feel part of the Group, which involves adopting the safety culture and quality requirements, is a challenge to be met in a short space of time.

Our engineering departments are working at maximum capacity to meet costs and deadlines, and we must not take any safety risks. I would like to add a priority: the complete overhaul of the current RGE, which I consider should be completed in the 'near future', with a view to 2035 (*see Chapter 2*).

Small modular reactors (SMR): Nuward®

Having been described as promising for many years, SMR projects are now finding it hard to get off the ground. Beyond the slogan 'small is beautiful', the economic model is being questioned (economies of scale, regulatory context). In the US, the Nuscale® project in Idaho was abandoned for profitability reasons. The American regulator has been mandated to develop appropriate regulations.



Reading parameters in the electrical switch rooms, Blayais

The technical options for the Nuward® project are proving too long to develop. In order to respect the schedule and costs of potential customers, the Group took the courageous decision to refocus its development efforts on proven technologies. The teams are working on the new design options. The next step will focus on completing the conceptual design, which should be achieved in mid-2026. The first-in-series of a 400 MWe reactor in France is planned for the early 2030s.

GEN IV fast reactors

In 2023, the MPs Raphaël Schellenberger and Antoine Armand made recommendations to remedy France's loss of sovereignty and energy independence, which have been slow to materialise. Among the errors pointed out by the MPs: having *"shut down the Superphénix fast reactor in 1997 and failing to maintain our lead in research and development for fourth generation post-2019"*. The lesson they draw is just as pertinent: *"without research, we are doomed to fall behind: research needs visibility and resources to anticipate the next five decades: closure of the fuel cycle in the nuclear industry [...]. France must also make up for lost time in research and actively relaunch large-scale programmes on fourth generation, which is the only project capable of changing the scale of our need for imported uranium and significantly reducing the issue of waste, without resolving it at this stage"*.

During this period of reflection, other countries are investing (high-temperature reactor (HTR) in China, American and Indian projects, sodium and lead in Russia, fast reactor in Japan JSFR, etc.), most with the objective of drastically cutting down on the use of uranium resources that are bound to run out.

In December 2024, Framatome and the Japan Atomic Energy Agency (JAEA) signed a strategic cooperation agreement for the development of fast reactors. This partnership allows them to pool expertise and consolidates Framatome's position on the global innovative technology market.

The ASN-IRSN merger: expectations and obligations for operators

On 1 January 2025, the creation of the ASNR will transform the technical dialogue, which will now be conducted by a single body rather than two, and will change the relationship between the safety authority and the Operator. This is an opportunity to reaffirm the operator's primary responsibility, which may have been dampened by the multiplicity of studies, questions and assessments that did not always show the hierarchy of safety issues. Though, unconsciously, it had become comfortable to leave the initiative to the safety authority, the moment seems to have come to more clearly define the operator's responsibility to build a nuclear safety strategy and to show conviction and foresight.

The objective is not so much to improve relations, which are good, but to always set out the issues, define priorities and highlight the in-field realities. Constant technical dialogue and greater access to the nuclear power plants for ASNR engineers and experts can only help.

I suggest that the birth of this entity be marked by stabilising the reference standards. It is a good sign that the ASN agreement is keeping the safety objectives of the 4th periodic safety review of the 900 MWe reactors for the 5th review.

Nuclear power as an adjustment variable

For economic reasons, with high fixed costs and low variable costs, most of the world's nuclear power plants operate at base load, i.e. at full power. Nuclear energy accounts for a relatively small proportion of the energy mix, and in the absence of a decarbonisation policy, production/consumption is balanced by gas or coal-fired power plants with low fixed costs and high variable costs.

Since the 1980s, as a result of the political decision to opt for a predominantly nuclear energy mix, French reactors have been able to modulate their power (load following) to balance production and consumption and regulate grid frequency (*see 2023 report*). This flexibility is a technical achievement, possible thanks to 'grey' control rods that moderate the neutron reactions.



Addicted to load following

Beforehand, this operational flexibility (a drop followed by an 80% increase in thirty minutes) was obtained over a fraction of its operating range, during the morning and evening demand peaks. The massive arrival of new sources of renewable electricity, both intermittent and

priority on the network, has multiplied load changes. These variations are not without risk to the safety of the electricity system (including blackouts), nor are they without constraints on the operation of our facilities. In the long term, they call into question the economic model.

From a dozen reactors modulating over the course of a day, it is no longer unusual for around half the fleet in service to be affected. The operations teams are used to the exercise, but a power variation is not a trivial event. Outside all other activities, maintaining enhanced serenity in the control room is vital. The unpredictability and short notice of these strong modulations disrupt the planning of activities, scheduled maintenance and periodic tests, affecting all professions and stakeholders, including contract partners.

On a more macroscopic level, the organisation of technical outages will have to be adjusted and will require ensuring the availability of a large number of reactors to compensate for the intermittent nature of renewable electricity. In winter when there is a great demand for power from the grid, wind power can vary by more than 20 GW in a few hours. Similarly, nuclear power reduces in the middle of the day and has to respond to the peak demand at nightfall. Modulation has gone from flexibility to constraint, with nuclear power having to meet the demand on its own or with hydroelectric power, unless we resort to using thermal and carbon-based means.

In addition, load following inevitably has an impact on the plant, which is more frequently subject to significant cycling. The increase in emergent issues is not glaringly obvious, but we will feel its effect over time.

I believe that the priority given to renewable energy in a one-sided nuclear/renewable energy complementarity leads to variations in power output. These variations should be avoided because of their potential risk to safety, particularly in terms of reactivity management, and their impact on the maintainability, longevity and operating costs of our facilities.

IT IS ALWAYS THE PEOPLE THAT COUNT

The value that we place on work, between personal fulfilment and the collective goal, what are the reference points and driving forces for a new generation in search of meaning in a complex and uncertain world? *"We must accept the complexity of the human condition, always put things in context and not lock ourselves into certainties. Today, even the most advanced sciences are faced with uncertainties. That is why teaching must involve confronting these uncertainties"* (Edgar Morin).

Safety culture provides an opportunity to prepare for this challenge and to give meaning to the demands of our professions, to the benefit of collective performance.

All the Group's small victories, whether in engineering or at the plants, are fine demonstrations of the strength of a collective effort where every talent contributes in a spirit of solidarity to a shared objective. Failure feeds on individualism and compartmentalisation, but it is not inevitable. Success is a state of mind based on collective intelligence. Collective effort combines talent, shares out the workload, reduces the risks, and multiplies the results.

In 2023, I stressed the importance of finding the right balance between high standards and benevolence. To make do with an 'acceptable' level is to run the risk of a gradual and insidious deterioration. Like the Olympic Games, you must aim for 'faster, higher and stronger'. But there is no point in reinforcing the strong elements if even one weak link remains. Leadership is not about giving up on the weak, but giving them confidence and helping them progress, encouraging them to take charge so they can improve for the benefit of others. Collective performance is not achieved by maintaining the same level of performance or simply compensating for individual weaknesses. This is the major difference between using high expectations as the standard, rather than using the lowest common denominator! The leader must raise the standard! The safety of our complex systems depends on it.

Being sensitive to the human dimension of nuclear safety, I wanted to devote a chapter of this report to the challenges that the Group will have to face. Among all the possible challenges are those relating to organisation and people, in a world faced with new technologies ([see Chapter 9](#)).

In 2024, with the retirement of the nuclear attack submarine *Emeraude* after 36 years of active service and having been a submariner admiral and now inspector general, I would like to remember the ten members of her crew who died in the line of duty thirty years ago.

Industrial risk is still a major and sometimes fatal issue, even in a submarine that scrupulously respects diving and nuclear safety. The operator, or the combatant, must never forget the importance of humility, otherwise they may be cruelly reminded of it.



After having genuinely understood the risks of complexity, the Group's objective is to put theory into practice by developing responsibilities and margins for manoeuvre in the field.

Operations in France has seen significant progress in terms of intents and standards; the battle is now on their application, team management and standardisation.

Priorities regarding the independent nuclear safety oversight teams: their scope needs to be broadened and their practices harmonised in France, while resources need to be ensured in the UK.

Flamanville 1&2 power station

The long road from demonstration to the field

02

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Annexes

Abréviations

CURRENT STATUS OF NUCLEAR SAFETY

Acceptable results and events that call for vigilance

The indicators are globally satisfactory in both fleets, although the number of technical specification non-compliances has not improved in the UK and that of the number of automatic reactor trips has exceeded the target in France (29). Plant isolation events and alignment errors require increased vigilance.

We are still seeing reactivity management incidents in France (including new uncontrolled boration/dilution incidents). In the UK, there were three significant events:

- Reclassification to level 2 on the International Nuclear Event Scale (INES) by the Office for Nuclear Regulation (ONR) for an incident that occurred twice within a six-month interval in 2023: gas circulators failed to start up automatically after loss of electrical power supplies

- Failure of a main steam valve spindle; the Operator decided to shut down the four reactors equipped with the same type of valve until the components could be replaced
- Blockage of a fuel assembly suspended in a fuelling machine.

While the operational decisions were appropriate, these events call for better prevention measures with respect to facility ageing issues.

The recovery of some French nuclear power plants in difficulty is too slow, with a risk of wearing staff down and resulting in their disengagement. The DPN has strengthened its detection and support system (*see 2023 report*). Some 'operational recovery plans' are still too broad, while others are becoming more targeted with support from the DPN. This support mainly consists of challenging, measuring performance and managing plans. We now need to help improve practices in the field. In this respect, I appreciate that the Operations engineering unit (UNIE) is developing a catalogue of support missions of this type and that the DPN is moving towards less prescription and more support. The DPN launched a 'divisional support plan' in response to the series of incidents that occurred during the start-up of Flamanville 3 (*see Chapter 7*). The corporate level in the UK is also evolving the support function to be much closer to the sites.

Graphite and the AGR operating life

Graphite cracking and weight loss are inexorable phenomena which may determine the end of AGR operation.

Cracking in the graphite bricks of the core could prevent the control rods from dropping in the event of an earthquake, or generate debris that could jam fuel assemblies. There are two types of cracks:

- Key-way root cracks (KWRC) in the wedge notches that hold the graphite blocks together. This issue led to the closure of Hunterston B and Hinkley Point B, and could affect Heysham 1 and Hartlepool in particular, as their design is less earthquake-resistant than that of Heysham 2 and Torness



A C&I activity in the turbine hall, Flamanville 1&2

- Seal ring groove wall cracks (SRGW) in the inter-brick seals. These cracks are specific to Heysham 2 and Torness, and could create graphite debris. Tests have shown that the extraction of fuel assemblies remains possible, which means that their appearance no longer leads to the immediate end of operation.

However, graphite weight loss is shown to reduce neutron moderation. In this case, an incident involving water ingress in the core, such as boiler tube failure, would increase reactivity. Procedures are in place to counter this issue, and automatic control systems are planned.

In 2024, EDF Energy reviewed all the data, modelling and safety analyses on graphite. The closure schedule for the AGRs still in operation has been redefined: Heysham 1 and Hartlepool in 2027, Heysham 2 and Torness in 2030. Three-monthly inspections and regular reviews of safety cases and analyses will be crucial.

Industrial-scale management for stress corrosion cracking

Stress corrosion cracking (SCC, *see 2022 and 2023 reports*) is being resolved thanks to industrial-scale inspections and repairs, coupled with an effective policy of preventive replacement actions.

The industrial-scale implementation of new ultrasonic inspection processes (such as ultrasonic testing with conformal transducers (UTC) developed by Intercontrôle), automated welding, and the acquisition of this know-how by all those involved are helping to reduce collective doses and the length of outage durations. Robots for grinding weld beads have been developed, and the future EPR2s will benefit from this. More than 1,300 welds have undergone non-destructive examination or laboratory assessment. SSC monitoring will be part of routine maintenance by the end of 2025.

We still need to gain a deeper understanding of its cause and triggering factors, through wider collaboration involving all experts. We also need to accelerate the study of new solutions, e.g. overlay, compression clamps (MSIP).

Fire: better control of fire loads, segregation and calculations

In 2024, the French fleet was affected by two main transformers that caught fire. Whilst extinguished safely, this recurrence is unsatisfactory and is due to fragility of the electrical penetrations. Such an event had already occurred at one of the sites involved and the bushing in question had to be replaced; at the other site, the monitoring sensors were not used.



Technical visit after ATEX modifications in the turbine hall, Tricastin

Management of fire loads remains below standards in both France and the UK. I also note that the use of lithium batteries is increasing in portable tools: they must not be recharged unsupervised or near flammable materials, as was illustrated by a fire in a radiation-controlled area.

In terms of segregation, I now see fire doors that are closed properly, a sign of progress. However, several dozen floor drains were found to be non-compliant in France. A wide range of non-conformities also affect cable penetration seals, and a national task force has been set up; I will be monitoring the resolution of the problem closely.

Permanent units of professional fire-fighters are being set up on some French nuclear power plants. I will make sure their training and motivation is kept at a high level despite the low frequency of fires, and that sites take advantage of such units to improve their practices and fire culture. Above all, their presence should not be seen as a reason to neglect fire prevention commitments: fire is the main risk on any industrial site and the Operator must feel responsible. Fire culture also needs to be strengthened in the UK, as does the reliability of detection and suppression equipment.

In engineering, the number of periodic safety review studies is on the rise, often using sophisticated methods. The standards are constantly evolving to respond to increasing demands, with interactions between R&D and assessment during the reviews themselves. The methods for the fourth periodic safety review (RP4) of the 1300 MWe series are evolving compared with those for the RP4 900 MWe series, which also differ from those for FLA3 that has just started up, and those for the EPR2 are still pending. I believe that these changes should not be discussed in the heat of the moment. The drafting of methods for the fleet and the EPR2, which are in progress, should take advantage of these lessons learnt and aim for simplification. Above all, I saw that the engineering departments are overwhelmed with hundreds of 'computational' studies, making it difficult to draw global conclusions as regards the level of risk.

Engineering also needs to get closer to the heat sink

The heavy *Cévenol* rains during the month of October had no impact on the Rhône Valley reactors. The response organisation was mobilised, plant tours were carried out in advance, and the on-call staff were notified. In the region, the rainfall, the heaviest in 40 years, reached more than 600 mm in 24 hours. After any event of this type, we must verify our assumptions and standards (*see 2023 report*). I also encourage the plants to pay close attention to the surface water drainage systems.

At a French site on the coast, the massive influx of seaweed into the heat sink led to an automatic reactor trip. This event shows that we must continue to make progress, even if our means of managing such risks have been improved in recent years. At a UK site known to be sensitive to this phenomenon, I was able to see the progress made in predicting and managing these events. The heat sink there has received significant investment.

I saw modifications destined to prevent the risk of frazil ice which makes it difficult to dredge the intake channel and recover driftwood drawn in by the current. Elsewhere, in 2023, similar modifications had already exacerbated the flooding of a heat sink. In terms of hazards, I ask engineering to increase their efforts in the field so they can better assess the site configuration and the operating conditions. Studies based on drawings are insufficient.

Operate diesels according to best practices, it will pay back!

The re-internalisation of certain maintenance activities and practical training at the Maintenance and logistics unit (ULM) or in manufacturer teams, helps develop understanding of the equipment and skill acquisition. The condition of the ultimate emergency diesel generators (DUS) is improving through the practice of barring. I appreciate the intention to stop unloaded tests on the DUS diesels.

However, barring is not being extended to other diesels, and many tests are still unloaded and too short. Some incidents call into question the technical level of certain French nuclear power plants. For example, the maximum speed of a diesel was exceeded by almost 100% during an over-speed protection test, resulting in a complete overhaul: the protection device, object of the test, did not work and the operators did not monitor the tachymeter. The risk assessments will be updated by adding speed monitoring to the procedure: the issue seems to be more about restoring basic discipline fundamentals.

I reiterate the recommendations made in my 2021 report, calling for the uniform development of skills at all sites and for diesel generators to be operated and tested in accordance with best practices. This is all the more necessary given that the widespread development of intermittent renewable energy is weakening the reliability of power transmission systems.

In the UK, the reliability of emergency gas turbines remains insufficient despite the implementation of a recovery plan in 2023. One site has also experienced diesel generator reliability issues.

WELL-MAINTAINED FACILITIES, BUT THE WIDER ASSETS NEED INVESTMENT

The condition of facilities reflects the culture of the site. It varies from site to site, but is generally good. Safety-classified equipment is generally well maintained. Some parts of nuclear auxiliary buildings at French sites are run down, for example the control room.

Pumping stations have improved. By the sea, corrosion must be managed permanently throughout the plant; however, this is not the case everywhere. Rather than adding to the defect backlog (list of work requests), there should be teams dedicated to it.

At a UK site, there is moisture ingress in the CO₂ core cooling system due to reheater leakage, which could compromise chemistry control and equipment condition. In addition, equipment ageing can be the cause of notable events (*see above*).

While the defect backlogs are improving, the assets need more human and financial investment. Even though the work request process helps identify priorities among the hundreds of requests, other priorities tend to be left unactioned for too long when they have no immediate impact on generation or the general operating rules (RGE). I see a kind of disconnection between the process and a sense of ownership; a tendency to focus only on the prescribed, to rank priorities and justify deadlines rather than repair; a high tolerance to non-conformities and a risk of becoming accustomed.

Quickly dealing with what can be fixed and anticipating defects by maintaining assets must be the watchwords. The first assumes we have the ability to act effectively, the second to invest without succumbing to budget cuts ([see Chapter 6](#)). From a cultural perspective, individuals must feel they own the plant. Everything else will follow on from there.

NUCLEAR FUEL: A STRONG TECHNOLOGICAL ROADMAP

With five fuel assembly failures (0.072%), and none occurring with MOX, the French fleet's performance is good, without equalling the record of 2023 (two fuel assembly failures). M5 cladding corrosion appears to be well managed thanks to the increased iron content, but we have yet to understand the finer details of the phenomena. The number of friction spring failures due to SSC is reducing. Corrosion deposits on fuel cladding (CRUD) needs to be monitored, and efforts must continue on foreign material exclusion.

The product roadmap is well established ([see 2023 report](#)), and I welcome the scheduled introduction of intermediate mixing grids that provide significant margins with respect to departure from nucleate boiling (DNB). I believe it is essential that the EPR2 be incorporated into the fleet roadmap from the outset. In the long term, the number of products will double, which will require appropriate quality processes.



Hinkley Point B power station

A single fuel failure was observed in the UK in 2024. Investigations to identify the cause are under way, with results expected in mid-2025. This is a site where leaks had already been observed due to carbon deposits on the cladding, which led to oxygen injection and specific precautions during the shutdown and restart phases.

The fuel route remains a difficult area due to its complexity, and ageing and obsolescence issues. Two serious incidents illustrate this: a fuel assembly that was stuck in a fuelling machine connected to the core and, at another site, a fuel element that was stuck in a fuel assembly dismantling unit.

DEFUELLING WELL UNDER WAY IN THE UK

The defuelling of permanently shutdown reactors is progressing well. Hunterston B was fully defuelled at the end of 2024, and the first reactor at Hinkley Point B was defuelled mid-2024. At Dungeness B, defuelling is being carried out while the reactor is 'hot' ([see 2023 report](#)). It has been demonstrated that all fuel assemblies could be removed in these conditions, even those with poorer mechanical properties. Analysis is looking to justify that defuelling could also be carried out in cold conditions, which would be much simpler.

Significant progress has also been made in preparing for the transfer of sites to Nuclear Restoration Services (NRS) after defuelling. Delivery and receipt of fuel assemblies at Sellafield went well again this year, and investments have made the plant more reliable ([see 2022 report](#)).

OPERATIONS IN FRANCE: TEAM MANAGEMENT AND STANDARDISATION

Operations are still too inconsistent across the French plants. Working as a team must become systematic again as this is one of the fundamental principles that may have been eroded. In high-risk industries, communication and cross-checking are general principles: the situation may not be what you think it is, and even the most experienced staff can make mistakes while performing a task, even one that has been done a thousand times, especially a routine task ([see Chapter 4](#)). We need to verbalise the actions we intend to carry out and cross-check the commands we give the plant. A number of incidents in recent years, particularly those involving reactivity management, corroborate this.

While my observations deliberately focus on French operations, I note that there have been signs of declining rigour in the UK, e.g. technical specification non-compliances and plant isolation errors. The high turnover of recent years, which reduced the experience of teams, has been resolved at the sites I visited.

Reactivity management: the IGSNR has been heard

I welcome the fact that the DPN has published new standards and reactivity management guidelines. All reactivity-related activities will now be subject to prior communication and appropriate monitoring. These provisions fully reflect my recommendation voiced last year. It is now necessary to implement them in all control rooms, clearly and resolutely.

I met a team who quickly found them beneficial and praised their relevance: *“verbalising and cross-checking is reassuring for the team”*. In my opinion, these changes will incite a more global transformation of the way we conduct operations, in addition to improving reactivity management.

This illustrates the benefits of ‘technical-orientated management of the disciplines’ ([see 2023 report](#)), which defines and standardises practices. It is essential to uniformly cascade the expectations down through the sites, which can require managerial courage and the ability to manage conflict.

Training: a driver to achieving consistency in operations

In addition to the technical-orientated management of the disciplines, training must be the other pillar for standardising practices and behaviours. I have seen some good practices in certain teams: preparation of ‘boards’, going back to the technique behind the procedures, simulator themes reflecting difficulties observed during a shift, training without procedures, management presence at simulator sessions, good links with the Joint training department (SCF), etc. But these good practices may be specific to certain teams, and other teams or other sites may not feel concerned. As a general measure, I welcome the deployment of the Saturne digital mini-simulators in all the operations departments. I consider that instructors observing the shift teams in the main control room, as practiced by some SCFs, is a basic requirement of the role.

Training must be standardised, and it is vital that the roles and responsibilities of the DPN and the Operations & engineering training department (UFPI) be reassessed. Training in theory and operations in accident conditions is provided by the UFPI, while training in normal operations is essentially provided by immersion in a team. Trainees then learn the habits of their team, whether good or bad. Some operations departments compensate by allocating very good operators to a ‘skill centre’ that trains all future control room operators. This good practice also reveals a shortcoming. The time has come to rethink training in normal operations and in control room practices, as well as the role of the UFPI in this respect.

I also think it is necessary to strengthen the UFPI’s authority when it comes to certification and refresher training. I ask the plants to stop issuing equivalent certifications like those during the Covid pandemic, which permitted postponing certain refresher training courses. I invite the plant directors and their independent nuclear safety oversight teams to take a closer look into this matter.

Moderate load following

Load following has been used for decades to balance high-demand peaks in the morning and evening. But the massive development of intermittent renewable energies, which have priority, is forcing nuclear reactors to perform many more manoeuvres (2000 in six months). Less predictable, they occur at any time of day, their schedule is constantly changing, and they affect a larger number of reactors. I also observed the pressure put on the control room operators by the grid operator.

While load following within the authorised range is a training and skill factor, its wider use puts certain teams to the test. It also raises questions when it comes to shutting down a reactor that has just been re-started after an intense unit outage, in order to give priority to another low-carbon energy source.

We need to think about ways of guaranteeing base-load nuclear generation, better load balancing between producers to adapt to consumption patterns, and giving earlier notice of reactor power variations to make sure control room teams can prepare in a serene environment.

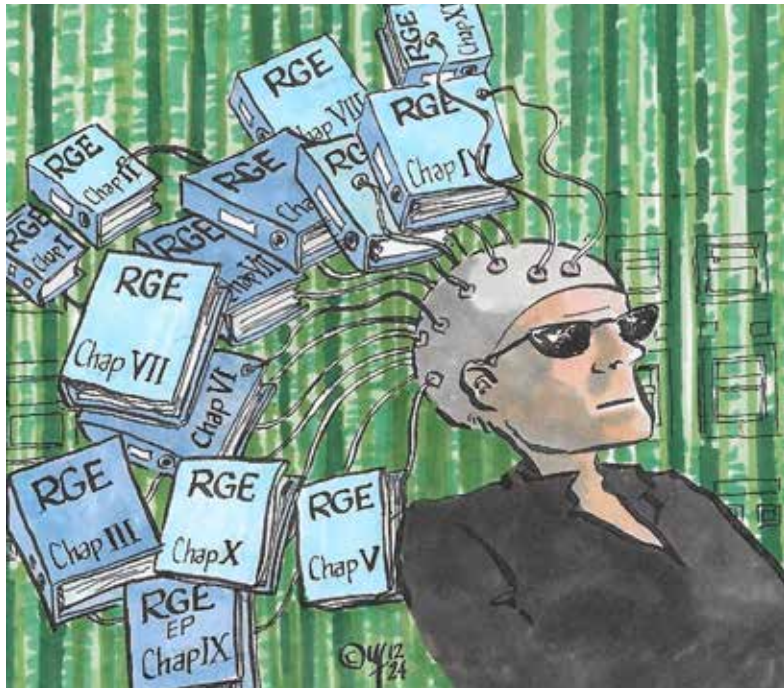
WE DO NOT OPERATE A NUCLEAR SAFETY DEMONSTRATION BUT A REACTOR

Dealing with complexity recognised as a priority

There is a widespread and beneficial awareness of the urgent need to reduce complexity because of the problems it poses to nuclear safety, as reflected in the ASN’s decision to devote its steering committee on social, human and organisational factors (COFSOH) to the issue. However, there are still powerful obstacles to simplification ([see Chapter 9](#)).

In my view, several DPN initiatives are positive:

- Elimination of formal managerial field visits (VMT), replaced by discussions on what has been seen in order to identify areas for improvement
- Technical-orientated management of the professions, already visible in operations ([see above](#)), to prompt dialogue of practices and techniques, rather than giving free rein to the interpretation of texts
- UNIE’s strategic objective to simplify operations in the field.



Memorising the RGE

The crucial stage of reviewing the RGE

France has set itself apart from international practices in terms of its RGEs, including for EPRs. FLA3 is a clear indication that our overly sophisticated approach has reached its limits. Without reaching the same level, the fleet RGEs are following a similar path. The dilemma facing the staff at nuclear power plants is: *“you have to choose between the letter and the meaning”, “you tend to think more in terms of technical specifications than in terms of the plant”* and *“you give precedence to knowledge of the rules rather than knowledge of the plant”*. There is a risk to nuclear safety. Fortunately, there is real awareness and the work has commenced.

I am in favour of adding a rapid simplification to the ‘RGE of the future’ project by the mid-2030s, without changing their structure but by applying a few concrete principles. This could involve no longer incorporating hazard requirements (RASA), removing controlled shutdowns for an accumulation of group-2 action conditions, carrying out repairs on the ‘as is’ state rather than performing a controlled shutdown, and removing the Flamanville local emergency support centre from the technical specifications, etc. These proposals, which have been acknowledged in principle by the ASN, are in the interests

of nuclear safety and reflect my recommendations. I encourage implementing these as quickly as possible.

I believe that we need to seize this opportunity to drastically reduce the number of nuclear safety criteria in the periodic tests, which should only cover the major functional parameters. The RGE will never be able to cover every aspect of equipment availability, which is based on plant tours, maintenance, intimate knowledge of the equipment by the owners, and periodic testing. Determining equipment availability requires skill, discernment and responsibility. Ticking the boxes of an ever-increasing number of criteria will not dispense with this. In the same spirit, I call for better understanding of orders of magnitude and time constants in the definition of criteria and their measurement.

In my view, the EPR2 RGE should incorporate these ideas from the outset, which presupposes the overall management of the strategy for developing these very rules ([see Chapter 7](#)).

Engineering: the field and the ‘reasonably adequate’

The engineering units, which work hard and with a wide range of skills, are experiencing three weaknesses:

- Taylorism: through the proliferation of studies and their division into sub-studies, we end up losing the original meaning and global vision
- Insufficient frequency of field visits and knowledge of operations and their OPEX
- Rapid growth in the number of staff, with an initial training programme that has yet to be implemented on a large scale, despite some progress at EDF and good practices at Framatome. Immersive training at nuclear power plants and technical management capacities are not commensurate with the volume of new recruits ([see 2023 report](#)).

To develop a sense of the notions of ‘good design’, ‘right balance’, and ‘reasonably adequate’, I believe we must value practical experience in the field, engineering judgement, understanding of orders of magnitude and meaningful values, and responsibility; *“when you don’t want to take responsibility, you ask for a safety demonstration”* ([see Chapter 9](#)).

INDEPENDENT NUCLEAR SAFETY OVERSIGHT: NUCLEAR SAFETY WATCHTOWERS

At the sites: improve competence and resource management and the ability to stand back

At the UK sites, the Technical Safety and Support Manager (TSSM) - Nuclear Safety Group (NSG) tandem is proving to be solid. Although the INA makes relevant observations, management of resourcing continues to struggle, and I repeat my alert. The situation at the French sites is improving, but some plants still suffer despite having

converted auditor posts into nuclear safety engineer positions. I call on the corporate services to resolve these problems.

On the French sites, the safety engineers lack perspective because of the narrow framework of unit assessments and the complexity of the RGE. As they are experts in RGEs, they find themselves on the analysis front line. However, I was pleased that some safety engineers were able to give me a high-level assessment of their plant's safety, and that they carry out annual *post hoc* analyses of operational decisions. UNIE is re-examining the framework of the unit assessments and extending it: I shall be following this welcome initiative with interest.

My 2023 report deplored the fact that the training, juries and supervision of safety engineers pushes them to think only in terms of the RGE, ruling out any duty of discernment. Dogmatism does little to promote the image of a position that should be about engineering rather than simple auditing. Furthermore, nuclear safety is at risk when *"we are unable to make the letter and the sense coherent"*. The new core skills handbook for nuclear safety professions takes note of this, which is important.

Changes in the corporate services

The DPN's Nuclear Inspectorate (IN) is moving towards performance assessment rather than just evaluating compliance. This is a welcome change. Integration of its nuclear safety assessments into the WANO peer reviews, initiated a few years ago, is now total. At the same time,

IN will be conducting more reactive inspections on targeted subjects, which is also positive. It expresses relevant points of view.

Over the past few years, Independent nuclear assurance (INA) within Nuclear Operations's corporate services has expressed solid views independently. In the period of leadership changes at the INA and the ONR, it is important that the INA maintains their independence and presence in the field.

Fragmentation of the independent nuclear oversight remains in engineering and projects

Whilst independent nuclear safety oversight teams exist in all the engineering and project units and they are involved in a growing number of bodies, a large disparity exists in the way they work, their knowledge of the field, the impact of their opinions, and their contribution to nuclear safety.

I appreciated the fact that some independent nuclear safety oversight teams (DIPDE, DTI Framatome) examined skills and training, while others (DIPDE) highlighted the risks of Taylorisation.

Piecemeal, fragmented and diverse, the independent nuclear safety oversight teams in the engineering and project units lack cohesion and an overview. They must quickly find their place and assert their legitimacy in the new organisation.

RECOMMENDATIONS

In view of the disparity of control room practices, I recommend that the Directors of the DPNT and the DPN review the training arrangements for normal operation and collective main control room practices.

In view of the recurring technical incidents in the AGRs, I recommend that the Managing Director of Nuclear Operations strengthen the resolution of their root causes, the management of OPEX between sites, and equipment maintenance plans.



The trend in industrial safety results calls for a response, near-miss accidents could have been more dramatic. Awareness and improvement programmes are not enough, they must be translated into concrete action and put into practice every day.

In France, contamination control, a subject of attention, is progressing; the collective radiation dose is stagnating. In the UK, radiation protection results remain stable and at a good level.

Nuclear waste is a subject in its own right, which deserves our full attention.

Torness power station

Industrial safety and radiation protection: putting it into practice in the field

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AN OVERVIEW OF PERFORMANCE IN 2024

The industrial safety results for 2024 call for continued vigilance. A fatal accident occurred at Nogent, the result of a cycling accident on the commute to work. Accident rates are on the rise in both France and the UK, with the number of lost-time accidents nearly doubling at Nuclear Operations (12 in 2024).



Operations in an electrical cubicle, Saint-Laurent-des-Eaux B

On French sites, the weaknesses relate to working at height ([see below](#)), as well as regulatory compliance. Particular attention must also be given to hand injuries and other risks: chemicals, anoxia and explosion ([see below](#)). There has been an upsurge in accidents involving two-wheeled vehicles, particularly for the engineering entities in large urban centres. In the UK, the principal causes of lost-time accidents relate

to manual handling, badly stored items falling and a lack of situational awareness. I am also concerned that the work request backlogs will deteriorate safety conditions in the facilities (e.g. a piece of concrete falling in a building in poor condition).

I called the chapter on safety and radiation protection in the 2023 report *'It's behaviours that count'*. This year, I could add that *'It's work situations that condition behaviours'* ([see Chapter 4](#)). We need to deal not only with critical risks and vital rules, regulations and related checks, but also with routine activities and their practical difficulties. In the fields of industrial safety and radiation protection, as in nuclear safety, the issues of culture and leadership are essential in enabling employees to complete their tasks risk-free.

In this respect, I have observed some positive signs:

- Compliance with the vital rules, such as respecting lifting exclusion areas and checking that equipment has been de-energised, which has helped avoid potentially serious accidents
- Greater collaboration between safety professionals (less inclined to play the role of the police) and workers, all of whom are focused on finding pragmatic solutions
- Roll-out of programmes across both fleets, demonstrating the Group's determination to not be satisfied with current performance; Nuclear Operations has launched four such programmes targeting work at height, compliance with electrical legislation, the safety of high-risk systems, and the condition of existing building structures.

The companies recently acquired by Framatome will have to adopt their parent company's industrial safety culture and safety standards. This subject is being closely monitored by Framatome's Inspector General.

In France, collective dosimetry is being well managed during a period of high industrial workload but remains elevated and is only improving very slowly. In the UK, it remains low whether on the AGR sites or the PWR of Sizewell B. In terms of contamination, I highlight:

- In France, there were seven significant skin dose events, including two classified INES 2
- In the UK, an increase in transport-related events (radiological cleanliness).

INDUSTRIAL SAFETY: POINTS THAT REQUIRE ATTENTION

Working at height

Both fleets experienced a difficult year. Several high-potential events called into question the perception of risk, peer challenge, and worker behaviours. These events also cast doubt on the preparation of work in advance, the use of experts, and the relevance of risk assessments.

In 2024, in France, workers were exposed to the risk of potentially fatal falls due to badly deteriorated collective protective equipment (ladder cages and work platforms). Although these hazardous situations are often known, this information is not reaching the right level. The mechanism to identify such risks is not applied consistently across the sites, these non-conformities are handled too late, and an overview of the situation across the fleet is difficult to establish. I welcome the action taken by the DPN to remedy this situation. While the ten-yearly safety reviews result in significant investments to improve nuclear safety, the facilities contributing to industrial safety deserve the same attention.

A fall that could have been serious

In September 2022, a workplace inspector identified a risk of falling from a height at a steam generator worksite. This risk was neither tracked by the site (no work request or report of a hazardous situation), nor was it taken into account in the preparations for the 2024 outage. A lack of rigour in the preparatory inspections and poor appropriation by workers (pre-job briefing and time-out for safety) meant that the risk of falling was not identified. During the removal of insulation, a worker tripped on a foot stop as he was moving backwards and, unbalanced, fell 3 metres, fortunately without sustaining any major injuries.

As indicated in my 2023 report, a lack of knowledge and worker behaviours are the major cause of such incidents. These relate to non-compliance with the basic expectations: not wearing or incorrectly using harnesses, climbing on or through guardrails, or not closing platform hatches. Other causes include inappropriate scaffolding modifications, improper storage of equipment with a risk of falling, or improper use of handling equipment. A condenser inspection cover weighing 500 kg fell on a worker, injuring their thigh and ankle, but the consequences could have been much worse.

The UK fleet is more sensitive to the risk of working at height since a fatal accident in 2010. Investments and a systematic inspection programme have been carried out to ensure that facilities are compliant.



Transformer inspection, Heysham 2

However, the high turnover of staff in recent years has eroded knowledge and risk perception. This resulted in several high-potential events in 2023 and early 2024. In response, the working-at-height programme is focusing on two areas: the quality of work packages, and behaviours with the 'behavioural-based safety' (BBS) programme.

Outages concentrate the risk of dropped objects, as confirmed by inspections such as 'early outage safety reviews'. Pre-outage training helps to remind people of the expectations. Sites are also encouraged to identify high-risk areas and install permanent protection such as mesh on railings and around access platforms.

In relation to working at height, the Hinkley Point C (HPC) site, again visited by the IGSNR in 2024, is rife with working-at-height risks, and site management is very attentive to this. In addition to practical measures applied in the field, reporting is encouraged particularly on high-potential events to help identify and resolve behavioural or organisational causes.

Chemical, explosion and suffocation risks

There are many risks in our plants, some of which are more insidious and deserve special attention. These include chemicals, explosive or asphyxiant gases. Though essential to ensure safe operation, they can become particularly hazardous for those carrying out activities near them or in confined environments.

The situation in France is mixed with regard to chemical risks: while some systems have received major investment (e.g. boron preparation), others have received none or suffer from a lack of maintenance, which increases the risk of leakage. In the UK, a refurbishment programme was initiated at the suggestion of the Chief Engineers. The condition of these systems (maintenance delays, defect backlog, etc., [\(see Chapter 6\)](#) deserves more attention.

Of a completely different nature, the risk of asphyxiation is difficult to detect, as demonstrated by several fatal accidents outside the nuclear industry. We have access procedures and robust detection equipment to manage such risks. Despite these measures, I have observed obstacles to their implementation in France, such as the shortage of oxygen meters and explosive gas detectors in plant stores.

The risks associated with explosive atmospheres are covered by specific regulations. Equipment compliance is generally well managed in both fleets. In France, modifications to sampling gloveboxes, although necessary, are taking too long to be completed (operating constraints). Compensatory measures are in place, but I am worried that workers will get used to working in a degraded situation over time.

DOSE MANAGEMENT: FINDING THE RIGHT BALANCE

Legislation sets the limits on occupational exposure to radiation over a rolling twelve-month period. Operators are also required to comply with the 'as low as reasonably practicable' (ALARP) principle, which demands finding the best balance between radiological, technical and economic aspects. To achieve such a balance, planning and preparation allow the various options to be weighed up and the best solution to be chosen.

In France, to reduce the source term (the dose rate of the plants), which is higher than the international average, the DPN has decided to launch a programme to clean systems (including chemical cleaning) and deal with hot spots. The initial results of cleaning operations carried out on four reactors in 2024 are promising. For all reactors, the aim is to make better use of cold shutdown and purification operations to further reduce the source term. I will be closely following the progress of these initiatives and their results.

EDF is also continuing to invest in various other initiatives aimed at reducing doses by improving prediction methods (with the help of the CADOR software), or by developing robotic non-destructive inspection techniques (NDT) to distance workers from areas at high risk of exposure.



Checking a dosimeter, Hinkley Point B

Development of NDT technologies: an additional advantage

In response to the stress corrosion cracking issue, the Industrial quality division (DQI) and its specialist partners developed a phased-array ultrasonic NDT technique [\(see 2023 report\)](#). This method has improved the reliability and reproducibility of the inspection process. This technique was then further improved by adding robotics for measurement and recording. Automation of the inspection process has also helped reduce the collective dose significantly, as technicians can remain at a distance from the inspection areas during measurement.

In the UK, even though AGRs generate smaller doses, the gradual accumulation of graphite dust in certain areas is increasing dose exposure. Sites have to adapt to this situation within the scope of reactor lifetime extensions. The fleet's head of radiation protection has asked the sites to reduce the number of hot spots or, where they are unable to, to justify measures that can be implemented to reduce the dose rate. The fleet's ALARP committee will monitor the progress of the action plan.

NUCLEAR WASTE MANAGEMENT: A DISCIPLINE TO RESPECT AND WASTE ROUTES TO OPTIMISE

A very different regulatory burden in France and in the UK

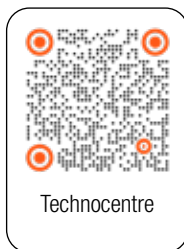
In France, the *Autorité de Sûreté Nucléaire* (ASN) has chosen not to follow Euratom standards and, in a strict zoning logic, considers that

any material from a radiation-controlled area must be classified as nuclear waste. As a result, much of its waste classified as 'nuclear' is not actually contaminated. This is not the way to optimise storage or recycling.

Nuclear waste is sorted into different treatment routes according to its characteristics and is subject to authorisation and, once secured, this system functions well. However, gaining authorisation for a new waste route is a tedious process (e.g. 15 years for battery disposal) and certain types of waste (e.g. soda, sludge, graphite) are still without an appropriate solution. Such waste has to be stored temporarily on site, which poses problems for both the operator and the Decommissioning & waste directorate (DP2D). Furthermore, authorisations are only granted for a limited period of time, making authorisation renewal a very time-consuming process which tends to put excess pressure on UTO's specialist teams. Is there any additional benefit gained from this workload?

The mobile resin treatment facility, MERCURE, operates very reliably. The nuclear fleet in France would not run as smoothly without this facility. We have to remain vigilant about its availability, which relies on only two units.

The Technocentre project at Fessenheim for the treatment of low-level contaminated metal waste is an excellent initiative for repurposing the site.



Confirming parameters, Tricastin

It enables metal to be re-used once it has been melted, thereby avoiding unnecessary storage.

Treatment of metal waste

Metal waste is currently sent either to the CIRES facility (Andra) in the Aube for final disposal or to the Centraco (EDF) factory in the Gard for melting. Storage at the CIRES unnecessarily exhausts the national capacity. The project to build a Technocentre to melt metal waste at Fessenheim, with a view to its re-use, is an excellent initiative that will avoid the unnecessary storage of metals that are not or only slightly contaminated. Pending the outcome of the public consultation process due to end in February 2025, it is scheduled to become operational in 2031.

The British approach is more pragmatic. The regulations allow uncontaminated waste to be treated as conventional waste even if it has been in a radiation-controlled area. This considerably reduces the amount of waste that needs to be placed in disposal, decontaminated or incinerated. Qualified technicians sort the waste on site and transfer it to the appropriate waste routes. These waste routes have remained unchanged for many years, with the same partners and processes. All the same, it has to be noted that there has been a recent change regarding waste containing graphite dust (e.g. Hoover bags), which must remain stored on site pending radiological characterisation.

Making the profession more attractive and improving equipment

In France, I have found that waste treatment jobs require experienced and motivated staff. Their work needs to be more valued.

Waste-producing disciplines are not sufficiently committed to providing reliable waste estimates. There are too many non-conformities associated with the at-source sorting of waste by work supervisors. This creates an excessive workload for the worksite support services (PGAC). The resulting dosimetry could be avoided. In addition, waste treatment facilities and their handling equipment are unreliable: they are ageing, experiencing obsolescence problems, and suffering from a lack of maintenance. I note that the DPN has initiated investment projects, the progress of which I will be following.

In the UK, the effluent treatment facilities have benefited from a refurbishment programme (e.g. digitisation of the control room in waste treatment facilities). The use of shredders and compactors makes it possible to optimise the volume of waste produced in radiation-controlled areas. I would encourage French sites to follow suit.

End of generation for AGRs: waste inventory before handover

The forthcoming handover of sites to the Nuclear Restoration Services (NRS) adds a new dimension to waste management. Requirements dictate that Nuclear Operations must provide NRS with an accurate inventory of all the waste remaining on site at the time of handover (e.g. materials from fuel assemblies, radioactive sludge and resins), including waste stored in the waste voids since the start of operations. A great deal of work is currently underway to ensure the accuracy of the inventories, which will need to be kept up to date.

RECOMMENDATIONS

In order to bring the dosimetry of French reactors up to international standards, I recommend that the Director of the DPN ensure implementation of the clean-up plan to reduce the source term, and during shutdown phases, under the ALARP principle, pay particular attention to the right balance between optimising the schedule and purifying the circuits.

In the nuclear waste processing and handling facilities, the lack of investment and maintenance is causing reliability problems. I recommend that the Director of the DPN continue with the investment and maintenance programmes for these facilities.



Consideration of human and organisational factors is an integral part of the history of nuclear safety.

The nuclear industry has learnt this lesson too often to its detriment and still has not mastered all the practices involved.

From an approach that sees people as the source of error, should we now move to one that sees people as the solution?

Everyone has a role to play in this change of perspective.

Blayais power station

The human factor: a source of error or factor of safety? 04

WHY USE AN APPROACH BASED ON HUMAN AND ORGANISATIONAL FACTORS (HOF)?

Industry-defining accidents

Three Mile Island, Chernobyl and Davis-Besse represent three of the four major accidents or events in the nuclear industry with a human and organisational factor (HOF) root cause. Other industries are no exception, e.g. petrochemicals (Seveso, Bhopal, AZF), space (Challenger, Columbia) or aviation (Air France Flight Rio to Paris). These events have profoundly changed the design and operation of our reactors. Their analysis has also helped to better understand what drives human activities, by rebalancing the behaviour of workers and that of the organisation and management. Notably, they have allowed us to understand that, in numerous events, the information was held somewhere in the organisation but had not been passed on or heeded.

Fostering humility

Today, more than 80% of all nuclear safety events involve HOF. They can be due to:

- Individual reactor unit or equipment errors leading to the automatic trip of a reactor or the isolation of an entire cooling system
- Poor operational decision-making resulting from, for example, an erroneous analysis of the situation
- Differences between the plant's actual state and its 'mental' representation in the control room, including the collective perception (the 'tunnel effect' syndrome)
- Gradual drift from good practices and becoming accustomed to deviations which can lead, as happened a few years ago, to a situation where a site's emergency generators failed to meet the earthquake resistance criteria.

Learning better from events

While events take many different forms, their systemic analysis has enabled us to deduce their nature; leading up to the final action that triggers the event, precursors can always be found, latent organisational weaknesses or lines of defence that have been weakened or broken. The aim of HOF is to better learn from these analyses, to determine

the human and organisational root causes, and to draw lessons based more on the skills and collective culture rather than on technical and documentary aspects. In France, these issues led to the reshaping of the event analysis method in 2023, based on a considered approach more proportionate to the risks. This was an IGSNR recommendation and its real effectiveness needs to be measured. In the UK, the Human Performance Evaluation Tool (HUET) has already been in place for several years and is a mature analysis method, but fleet analysis and trending of the causes could be better exploited. Regardless of the method, the quality of the initial gathering of facts is key to the process, and I encourage management to involve those with HOF skills as early and more systematically as possible.

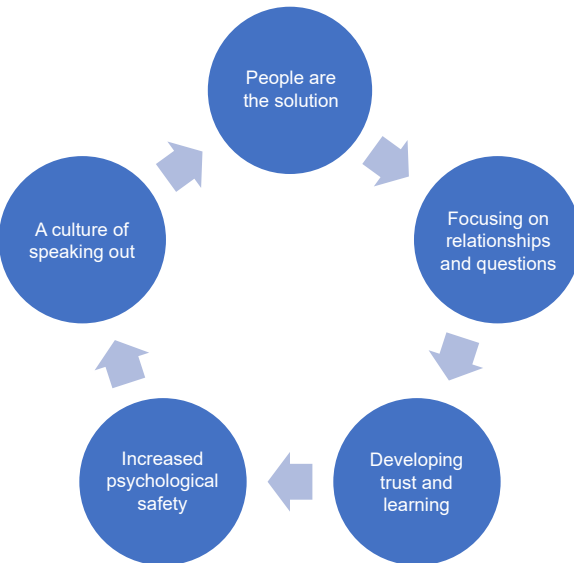
Learning from everyday activities

Taking an interest in events is not enough. We measure our performance by our failures, but we must also learn from the vast majority of activities that 'end well'. They can teach us about what compromises were made by workers in 'real life', or the adjustments and compensatory measures made to counter the organisation's weaknesses. They also confirm what works, we need to talk about this too. Regular work group discussions and renewed field presence reinitiated at French and UK sites are going in this direction, as is the advice of human performance leads and external feedback (IN, INA, WANO).

DO WE REALLY UNDERSTAND HUMAN AND ORGANISATIONAL PERFORMANCE?

Do not be limited to a 'tools-only' vision

Human performance is often equated with ensuring the reliability of activities. In this framework, the objective is to prevent people from making mistakes by deviating from the planned and prescribed. The key is to comply with the rules, to follow procedures properly, to implement practices that prevent error, and to identify countermeasures for pre-identified risks. Nevertheless, this representation of performance, which likens the human being to an idealised operator scrupulously following a list of instructions, ignores reality.



Clive Lloyd – “Next generation safety leadership” – the cycle of trust

Active and latent errors

An over-used approach to human performance can lead to efforts being focused primarily on preventing active errors, i.e. actions that lead to immediate undesirable consequences. However, a study by the US nuclear regulator on a series of accident precursors showed that the vast majority were linked to latent errors (e.g. design errors, inadequate procedure, failure to detect faults) which combine with other work environment factors, including active errors (*ref. J. Reason, 1990*). More subtle, with no immediate consequence, they tend to go unnoticed and should require greater attention.

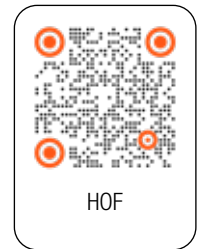
Highlighting the less noticeable

To limit sources of error, we need to learn from the daily work routine, aspects such as the context, the working environment and the quality of support. François Daniellou¹ illustrates this in one of his books: “*Work has a visible dimension (behaviour) and invisible dimensions (perceptions, emotions, memory, knowledge, reasoning, decision-making, movement control, etc.)*”. Recognising this opens up new

perspectives, such as identifying the factors influencing behaviour, the traps and drifts in work practices, and taking opportunities to improve work.

People are not the problem; they are the solution

Though people are fallible, they make things reliable. From this perspective, we can take a different approach to safety. By considering people as capable of adapting to unforeseen situations and showing initiative, it completely changes the level of importance we give them. On an individual level, and even more so as a collective, people can be a ‘factor of resilience’ provided we give them enough room to manoeuvre. In this renewed approach to safety, the organisation, the rules and the manager must be centred on how to ensure people perform, whatever the conditions.



The five principles of human performance according to Todd Conklin²

- Human error is normal. Even the best people make mistakes.
- Blame fixes nothing.
- Learning and striving to improve are vital. Learning is a deliberate act.
- Context influences behaviour. The system drives outcomes.
- How leaders respond to failures matters. How leaders act and respond count.

WHAT HOF APPROACHES FOR THE OPERATORS?

Giving new meaning to the human error prevention tools

Human performance error prevention tools were first deployed in the nuclear industry in the 2000s to anticipate, prevent and detect active errors. Twenty or so practices have been listed in international standards, the French nuclear fleet has identified six, while the UK fleet uses ten. On both sides of the Channel, we note the same decline in their application. The reasons given are different. In the UK, it is explained by the progressive turnover of people initially trained, with reducing support for newcomers. In France, a difficulty in giving the tools meaning as a result of a systematic

¹ François Daniellou long served as scientific director of the Institute for an Industrial Safety Culture (ICSI) and is co-author of ‘Facteurs Humains et Organisationnels de la Sécurité Industrielle, état de l’art’

² Todd Conklin, a nuclear safety culture specialist at the Los Alamos laboratory, is author of “The 5 Principles of Human Performance”



Main control room, Flamanville 1&2

implementation in 'instinctive' mode, and a piling-up effect with other safety tools (appropriation, procedural adherence, etc.). To relaunch the subject, Nuclear Operations has implemented the Behavioural-Based Safety and Human Performance (BBS and HU) programme, which re-establishes the basics by training everyone and coaching leaders. The French Nuclear Generation Division (DPN) has left the sites with more room for manoeuvre. In both cases, the most important thing undoubtably is for each individual to understand that even the best professional is not immune from making mistakes. Its success will depend on its ability to be self-critical or to be open to challenge from a peer, or even on group resilience.

Appreciating the reality of work through field presence

Several HOF initiatives are moving in this direction. The new 'presence in the field' approach promoted by START 2025 at the DPN enables us to take a closer look at work situations. Training courses are being rolled out on the sites. This approach, which I called for in the past, emphasises the need to establish a climate of trust, a guarantee of nuclear safety. The same applies at Nuclear Operations, with the additional development of leadership coaching reviews during which managers share what they have seen in the field and agree on the actions to be taken.

Work on leadership

At Nuclear Operations, resumption of the long-standing HULA programme ('Human Performance Leader') is consolidating knowledge, understanding and practices in human performance and nuclear safety culture. Based on mentoring, the objectives are wide-ranging with greater focus the principles of human performance, taking it further than just implementing error prevention tools. At the DPN, a drive to transform leadership is visible: the senior executive defines the expected attributes of leaders and the tools they can use (e.g. training modules), the sites define their own roadmaps and engage their teams in line with their principles and needs.

In France, an HOF culture that needs to mature

Through my visits, I was able to gauge how much more work needs to be done for HOF to be better taken into account in the workplace. While many underpinning actions are moving in the right direction and will bear fruit over time, the reality of the situation calls for a gear change:

- A lack of knowledge of HOF at different levels of the organisation, resulting in a very limited understanding of the phenomena and the implications
- An excessive 'tools' approach, which does not help to embed an HOF culture in the field
- Local expectations that risk infantilising workers, e.g. asking work supervisors to stamp documentation to record their understanding of an activity
- Misuse of the notion of 'just culture' by focusing on the definition of prohibitions and sanctions, rather than promoting the need for transparency and trust in the ability to report one's own mistakes without worry.

To overcome these difficulties and better embed the HOF culture at sites, I encourage the DPN to take advantage of the new nuclear leadership programme so managers can gain a deeper understanding of HOF. A high-quality training kit was recently made available to the sites; it is essential to ensure that a 'critical mass' of leaders become HOF-proficient, and to ensure its expansion to all employees. I would also suggest making better use of the Human Performance leads by encouraging them to take a stand on the site's issues (observations, feedback, etc.). Finally, I suggest reviewing the use of a 'just culture' notion to avoid the boomerang effect wherein 'organisational silence' takes over.

In the UK, consistency needs to be restored

I was able to see the slow deployment of the BBS and HU programme, and able to measure the inconsistent priority given to HOF. While, on certain sites, the HUET and HULA approaches have not weakened, on

other sites, it does not seem to be a particular expectation. The best HOF practices that I observed in the field were the result of initiatives led by department heads. This is the case at Heysham 2 with the 'crew resource management' approach (*see below*) in the operations department, or the HOF approaches in the maintenance department, which combine:

- Guaranteed periods of presence in the field every day from 10:30 am to 1:00 pm, with 'safety and quality' as top priorities
- Expectations with respect to the individual and collective accountability of employees: *"take 100% responsibility, act with integrity, put the team first."*
- Encouragement to learn continuously from their activities and to share lessons learnt: feedback from the field through the 'discovery clock' and sharing of feedback through the 'weekly safety meeting'.

Crew Resource Management (CRM)

Established in the Operations department at Heysham 2 following a benchmark with the Royal Air Force, CRM aims to make the most of observations made during simulator assessments. Heysham 2 has developed 'spider diagrams' to identify the strengths and weaknesses of its teams. These are used as part of an annual review of team compositions to balance skills and enhance their collective effectiveness.

HUMAN FACTORS IN DESIGN, WHERE ARE WE?

Plant modifications: reaching the limits

When engineering a plant modification, HOF analysis is required from the risk analysis stage onwards. Despite the progress made, HOF risks are diluted in the fifty or so cross-functional themes. It is still difficult to identify the effects that the accumulation of modifications have on the various disciplines. The conclusions of the complexity review carried out by the Tricastin site following the VD4 modifications came to the conclusion that: *"the operator, at the end of the chain, is required to adapt [...] we estimate that we are at the limits of our learning capacity"*.

On the strength of experience gained on the 900 MWe series, the DPN has decided to work more closely with the various disciplines upstream of the VD4s for the three first-in-series 1300 MWe reactors. The analysis focuses on two levels:

- Weighing up each modification according to its HOF impact (low, moderate or high), with a stronger impact analysis and better identification of the relevant disciplines

- Drawing up an 'overview of accumulations' for each discipline, with workshops on sites to take ownership of the difficulties and prepare for them.



Environmental plant tour, Flamanville 3

While this work is beneficial, it requires strong involvement from the disciplines, which is difficult to achieve uniformly across an operating site. I therefore encourage the first-in-series teams to pool their efforts, by discipline, and suggest that the DPN develop a structured approach from which subsequent sites could benefit. I am also aware this support will only have a limited effect, and I reiterate my recommendation to reduce the number of modifications for the VD3 N4 and VD5 900 series.

New-build projects: taking operation into account earlier

The integration of human factors into the design of new reactors is governed by international (IAEA guide SSG-51, standard NUREG 0711) and national standards. Human factor engineering has improved with each EPR project. Focused on the main control room, with great success, it has been limited to a few additional items of equipment at FLA3. At HPC, it has been strengthened in favour of buildings and equipment. For the EPR2, the best of both approaches has been retained. Thus, HMI and reactor control aspects remain very well integrated to the benefit of the operators. In the buildings, the issues of

space to carry out activities properly are better taken into account and must be preserved during all phases of the project.

Nevertheless, as I was told by some of the people I met that we still have to fight to get people to adopt a operator's viewpoint. When it comes to equipment, human factors are still seen as a constraint. Not enough thought is given to the activities associated with equipment (maintenance, alignment, etc.). The pressure of costs and deadlines, as well as the desire for standardisation, all makes increasing importance on HOF difficult, which is still perceived as something extra or nice to have. As a result, I urge all engineers to resist the temptation to think that the operator will adapt or that it will be corrected by training.

CULTURE, LEADERSHIP AND EMPOWERMENT: THE REAL LEVERS

Do not let a culture develop by default

A look at the FOH practices of other European Operators shows just how important it is for site management to work on developing a HOF culture. By default, the mechanisms of organisational silence will come into play, preventing safety-important information (particularly bad news) from being reported and incorporated into decision-making (see [Davis Besse](#)).

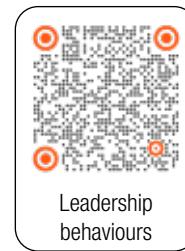
To achieve this, in addition to field presence programmes, Operators are investing in two main areas: the widespread dissemination of human performance principles and the creation of conditions called psychological safety. The latter, originally developed by Amy Edmondson², is based on the fairly intuitive principle that each individual must feel confident to dare to speak out in their team, to be a force for change, or even to challenge the *status quo*, all without fear

of being embarrassed, marginalised, ridiculed or blamed in one way or another.

Our exchanges with the civil aviation industry have made us aware of the 'right to make mistakes' developed in the culture of aviation companies. Reporting one's own mistakes is a duty, and management agrees not to punish those who do so. This is their approach to a just culture.

Leaders: architects of a new approach to safety

A culture that puts people at the centre takes time to build, and managers must be its architects. The traditional 'command and control'



style of leadership, which reduces operators to mere executors, is a thing of the past. The challenge is to promote demanding leadership that grows and develops commitment and accountability. Taking greater account of the human factor means changing the way we look at people. The challenge is to move away from a 'toolbox' approach towards a culture of human performance. This culture presupposes a learning organisation capable of driving continuous progress. It goes beyond safety

issues, and deserves to be promoted at the highest level, both at the sites and in the engineering departments.

RECOMMENDATIONS

Human and organisational performance requires a genuine knowledge of the principles and mechanisms of HOF, and I recommend that the DPN train all its employees in this area. This presupposes that everyone takes ownership of the meaning of these principles and commits to implementing them at their own level.

In view of the differences in dynamics between sites and the low penetration rate of the BBS and HU programme, I recommend that the Managing Director of Nuclear Operations make sure that the HULA method is uniformly adopted by leaders, and that improvement actions are enriched by HUET findings and analyses.

³ Amy Edmondson, professor of leadership at Harvard, author of 'The Fearless Organization: Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth'



Taken into account in all our facilities, earthquakes are taken very seriously but must not be over-valued in France and the UK, countries with low to moderate seismicity.

Though less appealing for an engineer, internal flooding is insidious: water can come from places you would never expect, seeping into where you do not want it. In the end, nuclear safety depends on in-field practices.

Earthquake and internal flooding: the theory and the practice

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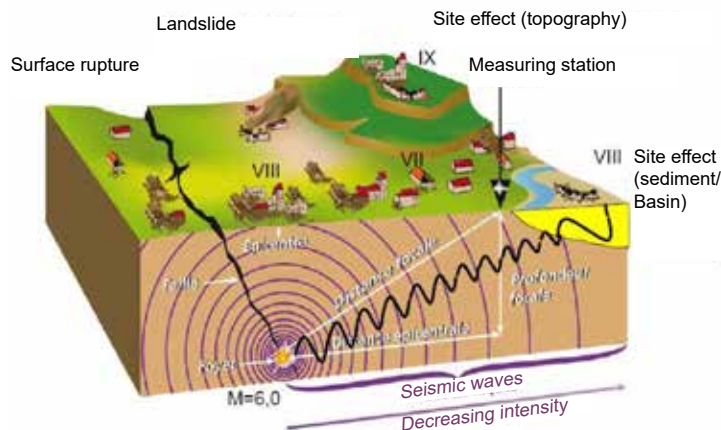
Abréviations

WHEN THE GROUND QUAKES

Geological faults move, their rupture causes a movement that propagates in the form of waves, and depending on its properties, the ground vibrates over great distances. Only a very powerful 'engine' is capable of generating such gigantic forces: plate tectonics.

Expertise and testing resources

Plate tectonics, geology, wave propagation, response spectra, structural calculation... at the crossroads between natural sciences and engineering sciences, earthquakes make for a passionate subject. The risk, however, is to over-value them when compared with other external hazards. After Fukushima, there was much more talk of earthquakes, which the reactors resisted very well, than of flooding, which was the source of the accident.



Earthquake and its propagation

At EDF SA, I see a great deal of knowledge, an efficient network, and high-quality cooperation. In Aix-en-Provence, I visited the new facilities of TEGG, the technical test department for geology, geotechnics and civil engineering. It works for both the hydraulic and nuclear sectors, and has been practicing field geology for 70 years. It has modern

testing facilities and remarkable skills. The third phase of the SIGMA programme looks promising. However, budgets to prepare the future need to be more certain. For example, the annualisation of the SIGMA 3 budget has not helped its management. Similarly, sufficient funding should be provided for the seismic monitoring network (RAN) for onsite measurements.

Updated in 2023, the strategic guidance paper on earthquakes rightly stresses the need to better integrate studies 'from the fault to the equipment'.

SIGMA

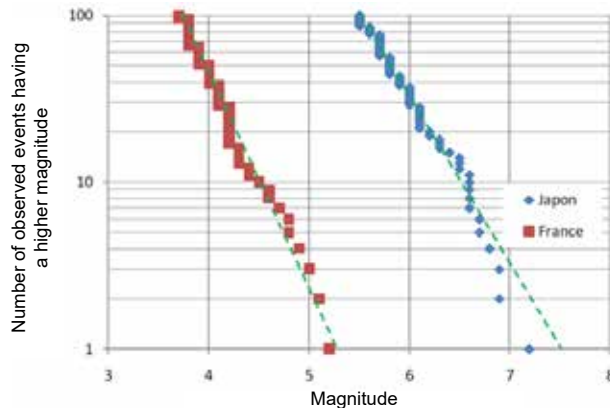
SIGMA, Seismic Ground Monitoring Assessment, is a seismology research programme initiated by EDF. It develops state-of-the-art data, models and evaluation methods for seismic events. SIGMA 1 was launched just before the Fukushima accident, SIGMA 2 was rolled out between 2017 and 2022, and SIGMA 3 started in 2024. Initially a Franco-Italian programme, it now integrates a large number of European countries, as well as the United States and Japan. It brings together nuclear operators, public laboratories, universities, and specialist consultants. Many dozens of theses and scientific articles are published after each phase of the programme. Its scope extends from fault physics to the spectrograms used by engineers, via seismic wave propagation, local ground response, optimisation of probabilistic models (PSHA) and control of uncertainties throughout the calculation chain.

France: a country with low to moderate seismicity

Located at a distance from the main plate tectonic boundaries (fault lines), France is a country with low to moderate seismicity. It is not Japan, California, the Anatolian Plateau or even Italy. Earthquakes are relatively infrequent and of modest amplitude.

The empirical Gutenberg-Richter law expresses the relationship between the magnitude and total number of earthquakes in a region (*see figure*): the frequency of an earthquake with a magnitude M is around 10 times greater than that with a magnitude $M+1$. Therefore, it seems that Japan is several hundred times more seismic than France.

Yet are we unconsciously compensating for our moderate conditions by accumulating margins?



Gutenberg-Richter distribution neighbouring French and Japanese sites

Seismic regulations: very French and very nuclear

The nuclear industry has, from the conception of its reactor programme, sought to protect itself against rarer and stronger earthquakes than other industries. The reference hazard is chosen according to a fundamental safety rule (RFS): establishment of seismotectonic zones, finding the strongest historically recorded earthquake in each zone, and translating it as close as possible to the site, resulting in a maximum historically probable earthquake (SMHV). The safe shutdown earthquake (SSE) in the nuclear safety case is then calculated by increasing the intensity by one degree or the magnitude by half a degree (equivalent calculations)⁴. A thousand years of parish records make this method possible: the description of the effects observed indicates the intensity of the earthquake. The fundamental safety rule has proven its robustness. However, it assigns a significant weighting to a single earthquake without including all events. The international reference methods (IAEA, etc.) are now probabilistic, i.e. probabilistic seismic hazard analysis (PSHA).

The SSE is transformed into an acceleration spectrum, from which the engineer calculates the structures. Initially global and highly conservative, these methods provide very substantial margins.

We are reaching the limits of the approach by multiplying and detailing the standard conservative calculations and associating them with increasingly severe hazards. In these conditions, the calculated

accelerations would, at certain points, reach 15 to 20 g, which no longer makes any physical sense. Similarly, piping calculations no longer meet acceptance criteria even though international experience shows they are perfectly resistant to real earthquakes.

Ultimate post-Fukushima earthquake: beware of extremes

After Fukushima, an earthquake significantly greater than the SSE⁵, named the 'hardened safety core earthquake' (SND), was defined in order to check that extreme situations well beyond design would not cause a 'cliff-edge' effect. The debate continues as to whether new reactors should be designed to withstand an SND using the same conservative methods as the SSE, or have their robustness verified by 'realistic' calculations.

I call for a grading between the design-basis hazards (SSE) and extreme hazards (SND) to be maintained in the case of earthquakes, where realistic methods are suitable. There is truth in the statement that *'too much is never enough'*, but are we not running the risk of building monsters that are out of proportion to the real seismic conditions? The fact that the new 'hardened safety core' for the plants were designed to SND should not set a precedent: they were very limited and had to be built quickly. In a new reactor, almost the entire nuclear island has to be justified in terms of the SND: applying design methods rather than checking robustness would mean using the SND rather than the SSE as the design-basis earthquake, which was never the intention. I endorse the recommendation of the EPR2 review committee in this respect.

Respecting this grading between the SSE and the SND seems all the more reasonable given that the margins of new reactors will be even greater than those of the existing fleet at start-up thanks to their design and the fact that the SSE has been further increased.

In the UK: comparable geology but different methods

The first AGRs were designed in the 1950s and 60s, and built from 1966 onwards without any consideration for earthquake risks. Seismic design began at Heysham 2 and Torness, followed by Sizewell B; a spectral acceleration defined at 0.25 g offers ample margin.

At the time of their first safety review in the mid-1990s, AGRs with no earthquake resistance were retrospectively qualified. It was easy to substantiate the reactor block as it sits on rubber pads. Buildings were reinforced, and plates and anchors were added to many items of plant. On some sites piles were installed and anchored to bedrock. Analyses carried out during subsequent reviews and post-Fukushima stress tests confirmed the margins.

⁴ Magnitude refers to the energy at the hypocentre (focus) of the earthquake; it is measured on several scales: Richter, moment magnitude, surface magnitude. Intensity refers to the effects observed at the surface, according to the MSK scale in particular

⁵ Acceleration of the SSE multiplied by 1.5 or a return period exceeding 20,000 years

The hazards are defined using the international method, PSHA, together with the British Geological Survey's seismic catalogue and local geotectonic maps. External experts adjust the weightings of the various factors and models; the ONR have oversight of the process. American databases supplemented by tests are used to assess the resistance of equipment. These are good practices.

Le Teil earthquake: confirmation or revolution?

The Le Teil earthquake on 11 November 2019, noted for its spectacular effect in certain villages, caused no damage to the Cruas reactors. It was similar to the kind of events that regularly occur in this area, such as the earthquake on 8 August 1873, which was used as the reference for the SMHV at Cruas. The new feature this time was the shallow hypocentre (1000 m), causing a small surface rupture (10 cm). This is a rare phenomenon for an earthquake of moderate magnitude (5), but more usual in countries prone to strong earthquakes (magnitudes of 8 or more with displacements in the order of 1 m, or possibly more).

This triggered an in-depth review of the seismic conditions at Cruas:

- A half-degree (MSK) was added to the SSE; this is still being debated as it may be excessive
- The spectral acceleration was reviewed using a propagation law reflecting the shallow nature of the seismicity in the area, and the reactor's earthquake resistance was verified
- Geophysical measurements are being carried out to detect any active faults.

Cruas has a number of solid advantages: it is built on rock, equipped with seismic pads, and has a robust design. I visited the facility; the



Geophysical inspection campaign

seismic pads and the foundation rafts are both well maintained and in very good condition. The technical subject relates to the search for faults neighbouring the site, the probability of surface propagation, and the consequences of such an event on nuclear safety. I was given

a presentation of the geophysical measurements already done and those pending; they are cutting-edge.

And at the power plants

The sites are focusing their attention on compliance and on the 'earthquake event'. In order to ensure that the qualification of equipment for accident conditions (MQCA) is maintained, several action plans have been drawn up following non-conformities:

- Nut locking devices missing or incorrectly fitted; I feel there is an urgent need to embed basic mechanical discipline rules
- Non-compliant anchors and support structures, in particular to non-compliant concrete layers
- Corrosion of diesel generator coolers; at a particular site, I have seen the onset of corrosion on previously replaced structures. Prevention must be constant
- A lack of rigour relating to securing mobile equipment and scaffolding.

International experience has demonstrated that the conformity and correct maintenance of such equipment are essential to their seismic resistance.

The combination of an earthquake with the stresses generated by hypothetical accidents in the safety case (e.g. pipe rupture) is one of the historical design rules. Today, earthquakes are also considered as initiators: they can damage unclassified equipment that can, in turn, damage safety-classified equipment (e.g. piping), which could, through a domino effect, damage safety-related equipment (e.g. a pump). This is known as an 'event earthquake'. I note that the exhaustive review of hazard-impact combinations in engineering and in the nuclear power plants is being finalised, and that the necessary reinforcements have been made.

After the earthquake at Le Teil, it was necessary to quickly review the verification procedures before Cruas could be restarted. I am surprised that they have not yet been rolled out to all the nuclear power plants.

The way forward: better appreciation of real risks

Some subjects remain topical, such as site effects (amplification of seismic waves due to specific geological features) or possible faults at Cruas ([see above](#)), and the natural sciences will continue to be studied in depth. But my impression of seismic risk is that of excessive conservatism, fragmented approaches and a preference for multiple calculations, the constant upgrading of reference standards and the juxtaposition of old-fashioned methods. Some experts believe that *"limited safety issues consume considerable engineering resources"*.

Nuclear reactors like ours, in a moderately seismic country, have considerable margins. This is confirmed by international OPEX from

major earthquakes. We need to take a step back, assess the entire chain of margins, and rediscover a sense of what is 'reasonably adequate'.

Various avenues have been explored, which I believe should be pursued:

- Adopting probabilistic seismic hazard analysis (PSHA), the international reference method
- Developing international assessment panels
- Examining whether soils can really transfer all the energy of our extreme earthquake spectra
- Examining methods for assessing the effect and harmfulness of shallow earthquakes
- Using international data on the behaviour of equipment under real conditions
- Developing the calibration of our structural calculation models using *in situ* measurements
- Moderating the use of 3D calculations and developing engineering judgement and good design sense.

INTERNAL FLOODING: AN INSIDIOUS RISK

Water comes from where you least expect it, and seeps in where you least want it. Even a moderate leak is capable of making its way to a control-command panel *via* unsuspected routes. In other cases, a break in the condenser circuit will cause large flows. Water and electricity do not mix. It is therefore necessary to protect distribution boards, control-command panels and motors against inopportune leaks from circuits and tanks, fire-fighting systems, drinking water, wastewater or rainwater, etc.

Field and engineering: two different worlds

I meet operators and engineers who seem to lead separate lives. The former have to deal with utility networks, gutters, ventilation ducts, cable trays, floor drains, inter-building joints, and so on. To complete the safety demonstration, engineering is overly focusing on high-energy pipe failures. Hundreds of studies are being carried out and calculation assumptions are being debated endlessly.

I believe ties must exist between engineering and operations, and between studies and practice; and this needs to be managed with a concrete and holistic vision of the risks.

Internal flooding at Nogent

In 2005 following an outage at Nogent, the start-up of the steam generator feed water supply caused a significant water leak on the roof of the electrical building where some drain valves had been inadvertently left open. The roof drains were blocked, and the water seeped through waterproofing defects in the roof and inter-building joint inspection hatches that had been left open. Hot water ran onto I&C and protection system cabinets, triggering inopportune commands, including an automatic reactor trip and the start-up of the safety injection system.

Moderating the safety demonstration

In addition to high-energy pipe failures, which, transformed into new LOCA studies (loss-of-coolant accidents, i.e. primary system breaches), can be a refuge, I think it is necessary to temper the classification mechanism. With the implacable logic that any equipment likely to have some influence on safety should be classified as safety-related, we end up classifying the stop valves on the drinking water circuits of HPC or the EPR2. This seems to be pointless, absurd and ultimately risky: if everything is classified, the classification loses its meaning.

In the same spirit, we are making event-based operations procedures and the general operating rules (RGE) more cumbersome. In the event of flooding, teams are asked to consult design studies, with their potentially countless combinations. When the time comes, rather than consulting studies on how to close a valve, understanding the equipment and systems in the field seems to be a safer option.

When it comes to internal flooding, the rules governing hazard specifications (RASA) can be either a beneficial reminder or an administrative nightmare (*see 2023 report*). I agree with the intention to remove them from the RGE (*see Chapter 2*). I have seen safety engineers drown in the search for timescales for controlled shutdown in the technical specifications after discovering perforated floor drains. Assessing repair times, safety issues and possible compensatory measures would have been more worthwhile than hours of trawling through documents without any success.

Though the EPR2 project is not free from such shortcomings, it has defined good design practices:

- High level of leak proofing in the secondary system cubicles
- Guaranteed leak tightness of rooms for a 1 m depth of water (10 m on the lower levels)
- Avoiding propagation between safety trains, for example by cable trays
- No roof drainage pipes in classified buildings (e.g. diesel generators)

- Collaboration with operators on effluent drainpipes to avoid ‘perfect by-passes for flooding’
- In the event of a blocked floor drain, existence of an alternative drainage route
- Absence of pipes embedded in the civil structures, etc.

I suggest taking a close look at the I&C rooms that are located near water sources (CCWS, refrigeration units, etc.).

The sites: standardising practices and training

The understanding of this hazard, which is not at the top of the list, varies greatly from one site to another. I carried out a field visit with a specialist who was committed, convinced and knowledgeable, who identified things on the plant and relentlessly pursued the defect work requests. Others are still a long way off.

A relevant initiative was UNIE’s ground-zero survey of a certain number of pipes: this has been carried out at some sites, while others seem to be unaware of its existence. Establishing an accurate image of the fleet’s level of conformity is essential. I am pleased that a novel solution for detecting blocked pipes is currently being tested: it will be an effective replacement for pipe sounding.

Ultimately, the aim is to manage the upkeep of floor drains, gutters, joints, floor openings, eyewash units, pipes of all kinds, etc., and to show that you do not have to classify equipment to take care of it. *“If we let things get out of hand, we’ll pay for it one day: there’s no such thing as minor equipment in a nuclear power plant.”* I would also call on the sites to check that they are well equipped with mobile pumps, hoses, fittings, etc. in case of emergency. And they should not hesitate to use the site emergency response plan’s (PUI) mobile means.

RECOMMENDATIONS

France is a country with low to moderate seismicity and our approaches lead to the accumulation of significant conservatisms in each area of the safety cases, I recommend that the Directors of the DSTID and DISC assess the margins ‘from the fault line to the equipment’, taking into account international OPEX and in consultation with the safety authority.

Safety from internal flooding is a matter for the sites themselves. I recommend that the Director of the DPN check the condition of any ‘non-process’ equipment concerned, insist on its proper maintenance, ensure that practices in the field are consistent, and ensure the availability of mobile equipment.

In the AGRs, water can flow through gratings from the top to the bottom of each ‘quadrant’ (one of four is enough for safety), limiting the risks. Care must be taken, however, in the lower part of the quadrant where pumps are located and where water will collect. I am also aware of two flooding events caused by isolation errors.

In relation to modifications, I appreciate the replacement and safety classification of the valves in the condenser water pipes at a French nuclear power plant; they are charged by gravity from the intake canal. However, I have not understood whether, once the VD4s have been completed, the sealed cable penetrations separating the nuclear island from the emergency feedwater galleries will be watertight in the event of flooding, as has already happened. In my opinion, they should be.

In operations, the ‘managerial guide’ is a first step, but it mainly refers to studies (dozens), and does little to describe the expected technical practices and attitudes. Its added value is considered low. I think it is essential to establish a field-practice standard, to reinforce plant tours, and to structure training. The insights and practices of field operatives, specialists and engineers, including those in the central services, are crucial.



Maintenance and testing guarantee nuclear safety and determine production.

On-line management of work (MoW) ensures that the reactors operate safely on a daily basis, and it deserves special attention.

The multi-year project (PLURI) paces the production cycles to ensure long-term performance.

Tricastin power station

From multi-year projects to on-line work management: rigour and agility

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MOW: A PROCESS TO BE STRENGTHENED

Return to the fundamentals to regain efficiency

In France and the UK, the work management teams coordinate the different disciplines that carry out maintenance activities (preventive and corrective), operations activities and periodic testing. It ensures compliance with nuclear safety requirements and manages concurrent activities and the associated risks. As part of the ten-yearly outage (VD) programmes, it also incorporates plant modifications that can be started with the reactor in service, before completing them during outages.

Embryonic in the early 2000s, the MoW process has since become progressively more structured, which has helped to bring the various disciplines together around the operator's priorities. From an activity centred on a few key people and meetings, the process has been structured around an organisation with dedicated resources and truly modular preparation⁶. Faced with a historically strong outage organisation, MoW has always had to find its place. With the increasing workload of sites in recent years (VD, SCC, etc.), the priority given to the MoW process may have waned, and I have noticed that many need to reacquire themselves with its purpose and principles. It seems necessary to filter out inefficiencies to regain direction and rediscover productivity, i.e. more productive meetings and greater accountability. As a result, the professional development of key stakeholders and the sharing of OPEX must be made sacrosanct.

MoW: poor relation in the production cycle

On both sides of the Channel, MoW structures the daily routine of a site and its operation, and constant managerial involvement is required for its smooth running. My visits show that this is not the case everywhere, with MoW remaining a poor relation on some sites, making the most of the resources they have. Yet, the impact of a weak MoW process (e.g. difficulty in stabilising the weekly programme and low schedule adherence) affects all areas: condition of plant (defect backlog), equipment maintenance (delayed preventive maintenance),

staff involvement (confidence undermined). Maintaining the generation plan, restoring our ability to transact work, deal with the defect backlog, carry out fundamental preventive maintenance, etc., is essential. In the UK, the MoW process is one of the four cornerstones (essential processes) that guarantee plant safety and reliability.

At sites in difficulty, longer outages require more resources and managerial attention, often with the risk of seeing staff disengage from the MoW process. It then becomes the first process that needs rebuilding. This means aligning and mobilising all the stakeholders, and breaking down barriers between departments, particularly engineering, operations and maintenance: *"people need to talk to each other rather than blame each other"*. High-performing sites are showing the way forward: in an ideal production cycle, MoW is positioned at the right level, meetings are identical to those of outages, and the same capacity for action is expected. The experience of these sites should be more widely exploited.



Turbine Hall, Tricastin

⁶ Coordination of all the disciplines to prepare the many activities of a work week or outage (planning, interface management, operating instructions, risk analysis, logistics, etc.). It lasts several weeks

Faced with change, make routine maintenance sacrosanct

On both sides of the Channel, MoW processes are affected by a number of changes.

In France, MoW has seen the addition of a considerable volume of preparatory VD activities, representing 70% of all modification work carried out during the on-line period.

In the UK, there have also been some very significant changes. The refuelling method at Heysham 2 and Torness moved from an on-load operation to an off-load operation. In addition to a statutory outage every three years, this now entails four to five outages, each of around two and a half weeks' duration every year. This new refuelling method has resulted in fewer available routine maintenance windows, which are more dense. Heysham 1 and Hartlepool have already had this refuelling method for several years now, and are experiencing the same difficulties. The unreliability of the fuel route regularly disrupts the schedule, putting maintenance and operations resources in a difficult position.

I urge both fleets to make routine maintenance windows sacrosanct, as preventive maintenance cannot always be replanned to accommodate schedule changes.

More than a matter of processes, a matter of people

Assigning the right people to key positions is crucial to the effectiveness of MoW. Performing sites invest in the MoW process with experienced people, while others see it, at best, as providing a feedstock for the outage organisation. It is important to rebalance the experience

in these two organisations. The resourcing arrangements for the MoW organisation needs to be closely reviewed. A successful MoW organisation requires many ingredients:

- Quality of resources coming from operations, e.g. work management leaders, secondees to the work execution centre (WEC)
- Work week managers/sub-project managers recognised by the various trades, and capable of building trust, initiating cooperation and driving priorities
- In France, competent maintenance project managers resourced to meet organisational requirements
- In the UK, work planners and work preparers with a maintenance or operations background.

Empowerment, teamwork and field presence: the keys to efficiency

While modular preparation is a key factor in the success of MoW, I have noticed that the energy devoted to it is disproportionate. Very focused on documentation and process standards, it does not take sufficient account of the in-field operational reality and collective working. This can lead to unreliable planning, as well as activities being cancelled. Several causes are frequently cited to explain this lack of operational efficiency:

- Cumbersome rules that make activities more complex, amplified by local over-interpretations
- A multiplicity of interfaces between the disciplines (logistics, delivering work permits, etc.)
- Work packages that do not sufficiently take into account the in-field reality, (missing, imprecise or excessive documentation)
- Too many computer applications
- Difficulty in obtaining spare parts
- Difficulty in obtaining work permits, or
- Safety constraints related to operating rules (technical specification constraints or conflicts).

Are we dealing with the problem correctly? Firstly, I encourage making people accountable for their work by involving them in the preparation of their activity. Regarding technicians as mere executors receiving their work prepared by others every day is from another century. Secondly, I encourage greater cross-functional working and solidarity; evidence calls for us to move away from a single-discipline mindset towards collective efficiency. Finally, I commend the initiatives of the sites that are putting all their energy into removing the last obstacles right up to the point of commencing the activity, in this way making the most of the investment in modular planning. It is therefore essential to save work packages that have been validated in this way, so they can be reused the next time work is planned. As well as making the work packages accurate and saving time, this capitalisation enables those preparing work to focus their efforts on more technically demanding work packages.



On-line modular preparation

RE-ESTABLISHING MARGINS FOR MANOEUVRE

Reactive teams: proof that it can be done simply

Modular planning is used to plan known preventive and corrective work. Reactive teams designed to deal with the unexpected are currently in great demand. They help maintain plant reliability and protect the schedule. Regardless of the way they are organised, which varies widely, their effectiveness, above all, depends on management commitment and engagement by the maintenance trades.

The many initiatives I noted during my visits attest to the dynamics at work in both France and the UK. They relate to the choice of working hours (one UK site recently adopted a round-the-clock organisation), the methods of management (by shift operations or not) and preparation (on-line or dedicated). Whatever the choice, there are three key points:

- Restore confidence in the way that defects are managed, because a breakdown in this can trigger a vicious circle: over-prioritisation, overloading teams, ignoring priorities and demotivation
- Allow operations to decide what is urgent and what is not, and to ensure that safety is compatible with the planning of the activity
- Ensuring that risks are always assessed and that reactive teams are not used as a systematic work-around to the modular planning process.

In my 2022 report, I praised the ‘tool pouch’ and ‘minor maintenance’ processes in the UK, which were designed to enable fast and efficient repairs. Following my visits, I realise that updating fleet processes and instructions has progressively reduced their effectiveness, or even made it impossible to apply them. We need to strike the right balance between rigour and flexibility.

Should we be satisfied with the defect backlog?

In France, as in the UK, the operator keeps a record of all work requests to be resolved. These are known as portfolios of work requests, or more commonly called defect backlogs. The state of these backlogs, which certainly illustrate the state of the plant, is regularly the subject of recommendations from IN, INA, IGSNR, and even WANO and the IAEA. Both the DPN and Nuclear Operations are engaged in an extensive reduction drive, which has halved these backlogs over recent years.

While this trend must be recognised, beyond the figures, are plants in better condition? I believe the situation should still be monitored closely. The proportion of backlogs under control is only the tip of the iceberg. Some work requests can be incorrectly assessed or be given a resolution deadline that is too far in the future, risking unforeseen consequences, e.g. an automatic reactor trip in France this year. The



Lifting a spent fuel flask, Cruas

part hidden beneath the surface, ‘secondary’ backlogs, can represent several thousand items, which questions the real level of control, or even the cumulative effect on system reliability. In addition, priorities and deadlines are not scrupulously met. Equipment reliability remains a recurring problem in France and the UK, and I will be keeping an eye on this.

What are the solutions? Some sites are taking responsibility, for instance, by imposing a more restrictive deadline of eight weeks for dealing with low-priority work requests (P3). Others are considering the option of reducing the volume of preventive work, which they feel takes up too many resources: although such actions have been taken in the past, this needs to be done in a structured way in conjunction with the centralised services. For my part, I question the inflexibility of the approach that involves refusing to incorporate any work requests in outage programmes that can be dealt with on-line. I am still surprised to see sites finishing a ten-yearly outage exceeding a hundred days, but with a larger defect backlog than before the outage. In the UK, some sites plan year-end campaigns to reduce defect backlogs with the aim of achieving the target, rather than smoothing out the workload. This does not seem to be a sustainable solution to me.

Furthermore, I believe it is important to allocate sufficient budgets to maintain equipment and invest in assets in a context of ageing facilities

and plant life extensions. A degree of contractual flexibility will also need to be maintained so contract partners can be called in when required.

Overdue maintenance: a risk of going too far

There are too many overdue preventive maintenance activities in France, with more than a hundred per reactor, with 33% on equipment important to nuclear safety, and in the UK, almost two hundred, with 20% on such equipment. Even though the proportion of these overdue activities remains low in relation to the number of preventive activities performed every year (around 0.2%), there are still many 'pseudo-overdue' activities attributable to the information system (EAM/AMS), but the situation is improving (halved in two years). Beyond the indicators, certain practices worry me. Clearly for reasons of resource allocation between on-line and outage management, on-line maintenance activities are being postponed and being managed by compliance deadlines, without requesting analysis or justification.



Maintenance activity, Hinkley Point B

This is not a healthy situation. The first risk is allowing an important activity to slip; some significant nuclear safety events have illustrated this in recent years. The second risk is that we become accustomed to exceeding deadlines and become more tolerant. In the past, one site lost confidence in its ability to comply with its preventive maintenance

requirements, and doubts about equipment availability eventually arose. We cannot afford to repeat such a situation.

What can we do? At the very least, we need to guarantee that any potentially overdue preventive activities are analysed before the deadline is exceeded. This may seem obvious, but this expectation is not always enforced. In the absence of anything better, the lines of defence should be doubled, or independent nuclear safety oversight audits should be conducted, at the very least. Ideally, as recommended by WANO, activities should be planned with a margin of 50% of the compliance deadline to cover technical or organisational problems.

THE PLURI PROJECT: GUARANTEEING BALANCE

At the crossroads

The challenges of the PLURI project are numerous, particularly since the fleet upgrade programme was introduced: safely guaranteeing production targets, enabling reactor lifetime extensions, carrying out the necessary refurbishments, ensuring that recurrent and asset maintenance activities are properly implemented, adjusting significant activities as best as possible between two ten-yearly outages, not to mention maintaining and optimising spend profiles.

Squaring a range of restrictive equations

The issues associated with multi-year planning are varied: fuel burn-up, regulations and industrial capacity. The disruptions caused in recent years, first by the pandemic and then the stress corrosion cracking issue, have made it necessary to frequently update the multi-year plan for outages. We should be proud of having found the necessary resources to make industrial programmes more realistic. Through a regulatory derogation, the ten-yearly outage of a site was able to be postponed on its request. Solutions to very complex situations have been found in discussions with the French nuclear safety authority. On an industrial level, the additional resources from the EPAT and EMAT (fleet teams providing support during unit outages) have been greatly appreciated by the sites. Although the station director is theoretically responsible for the multi-year programming of activities, it is regrettable that, in reality, there is very little room for manoeuvre.

Challenging the resilience of teams

"The crux of the problem is the workload", said one expert on the subject. The PLURI project remains the repository for all requests, and the industrial workload is considerable. For the fourth ten-yearly outages (VD4) of the 900 MWe series, the situation is one of a succession of intense outages with very demanding preparation work being carried out during the on-line period. Faced with the recurrence of these extremely challenging conditions, the sites are showing resilience, but normal operation no longer exists, and periods of respite

are rare. I have noticed that sites with long cycles no longer benefit from refuelling-only outages (ASR). Will they be able to maintain this pace?

Nuclear safety principles during outages: keeping focus

The managerial guidelines on multi-year planning demands that *“work on diverse safety train equipment should, if possible, be scheduled during different outages”*. This rule must be applied. I have observed some good practices. Some sites publish site-based reports certifying compliance with this requirement, identifying non-conformities and defining countermeasures. Other sites develop ‘outage identity cards’ to communicate the choices made and the related nuclear safety approach.

Nevertheless, I note that these principles can be called into question. Modifications have frequently led to rescheduling preventive maintenance, or to working on two diverse safety trains during the same outage. Investment decisions can lead to cancellations and impact a site’s optimised strategy. Finally, fleet technical issues can clash with site-based strategies.

Reasons to believe

In this highly constraining environment, it is important to recognise the momentum that has been generated to give PLURI its rightful place. I appreciate that, in accordance with START 2025, the technical directors are taking ownership of delivering the project: they have become the site’s technical conscience, patrons of the PLURI process and decision-makers for the medium- to long-term strategy. Asset management programmes are clearly their responsibility, *via* the governance bodies (defect backlog committees, equipment reliability committees, multi-year asset-investment plan, etc.). It would therefore seem logical that they become more involved in on-line work planning.

The PLURI project team manage the integration of documentation campaigns to ensure data is utilised, and, like the conductor of an orchestra, they set the site’s rhythm. Guaranteeing the short- and medium-to-long-term balance, the project will call for strong decisions

from the station director. At a time of investment decisions, it must also act as a compass and protect asset investments, which are essential to the service lives of our plants.

In the UK, the medium-term plan

While there is no exact equivalent to the PLURI project, the Medium-Term Plan (MTP) sets out a multi-year investment roadmap for sites. A portfolio of projects is compiled and weighted on the basis of information provided by engineering. It specifically includes reliability assessments, safety case reviews, ageing and obsolescence issues, and preparation for defuelling. This portfolio is then handed over to a dedicated delivery department (Investment Delivery). Each year, the portfolio is reviewed, and priorities and schedules updated. The position of the sites plays a key role in this exercise: the choices and scale of work vary greatly between the long-term operation (LTO) of Sizewell B and preparation for the end of AGR operation. While the number of staff dedicated to preparing and implementing investments is increasing, engineering is in a very difficult situation. It is very much focused on responding to short-term challenges rather than on its role as ‘technical conscience’ (managing medium- and long-term threats) and on the choice of investments.

The OPEX loop: a measure of continuous improvement

Achieving an effective MoW process involves understanding the reasons for the postponement of planned activities. This is a good practice promoted internationally. It works on two levels: firstly, by taking the necessary actions to ensure activities are successful at the next opportunity, and secondly, by correcting weaknesses in the modular planning and implementation processes. This OPEX loop is often neglected and is a source of frustration for workers, as the same causes produce the same effects.

RECOMMENDATIONS

On-line work management (MoW) is reaching the limits of its capacity to deal with the workload (defect backlogs, overdue maintenance, asset investment, lack of planning stability, etc.). I recommend to the Director of the DPN to improve efficiency and to find a better balance between outage and the pluriannual project. Consideration could be given to improving margins for manoeuvre in our standards, treating a part of the work request backlog in outages, and refining the scope of activities given to the reactive teams.

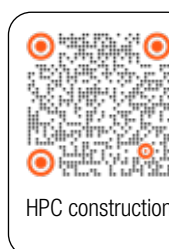
The implementation of maintenance activities is hindered by the increasing complexity of fleet safety processes, I recommend that the Managing Director of Nuclear Operations re-evaluate these processes to identify pragmatic solutions to make work implementation more efficient.



After the installation of the dome of the first Hinkley Point C (HPC) EPR in late 2023, the installation of the main primary system components was started in 2024.

The FLA3 EPR was connected to the grid on 21 December 2024 and is generating its first GWh.

Preparatory work on the first two EPR2^s began at the Penly site in summer 2024.



HPC construction

Placing HPC Reactor 1 dome

The new nuclear dynamic

07

HPC UNDERGOING A METAMORPHOSIS

During my annual visit, I noted a profound transformation of the site. The dome has been installed on reactor 1, mechanical, electrical and HVAC work is accelerating, and Framatome has commenced the installation of the first primary system equipment. At the start of 2024, the HPC project revised its schedule to better reflect reality. Industrial safety on site is remarkably well managed, from the field to the engineering offices.

Start of mechanical, electrical and HVAC (MEH) installation

The organisation of the project remains complex and there is still significant staff turnover. Tier 1 partners consider that they lack visibility of the planning of activities and wish to be more involved. Management in project mode naturally leads to a focus on schedule and budgets. The HPC credo 'Safety, Quality, Time and Cost, in that order' is more relevant than ever.

The prefabrication and coordination of civil engineering activities with the introduction of large components must be managed properly and, where appropriate, be the subject of operating experience (OPEX) for the second reactor and other EPR projects. The transition from a 'construction' approach to a 'systems installation' approach is



MEH installation, HPC

scheduled for 2026. The need for a systems integrator function has been recognised by the project.

I encourage the HPC project to continue the implementation of 'Project Bridge' to benefit from the skills of expatriates, whatever their nationality. Export control rules (access to documentation) and the time needed to find one's place in the organisation are obstacles.

The schedule calls for an acceleration of civil engineering and MEH installation. The rigour with which non-conformities are detected and resolved must be maintained. Configuration management is based on compliance with safety requirements and design specifications, as well as management of the physical configuration (matching the delivered/installed state with the design requirements). Project and building managers are focused on construction and installation. Configuration management must be monitored at every stage of the project. As soon as the first MEH systems are installed, the equipment must be properly protected: the HPC project is well organised in this respect.

HPC uses industrial processes such as S-MAG welding and phased array ultrasonic testing. I hope that the EPR2 project will benefit from such processes. The project is aware of and has taken into account the OPEX from FLA3 regarding the welding procedure for P355NH, including its material properties, testing, pre/post heat treatment and surveillance requirements. The quality of these welds requires the use of experienced welders, supervisors and inspectors, who must be available for these activities. The welding sector is under pressure, and it is difficult to mobilise extra support because of government requirements, relating to English language proficiency. These administrative constraints should be made more flexible to give priority to technical skills.

More quality with S-MAG

The S-MAG (Synergic - Metal Active Gas) process is a gas-arc welding method that protects the molten metal. Compatible with a wide range of metals, it reduces the number of passes thanks to its high deposition rate and is perfectly suited to automation. This process is used on the HPC site to weld pool liners. It has proved its worth by providing better control over liner deformation, reducing the number of defects by around 20% compared with traditional TIG welding, and increasing production rates.

Ensuring equipment compliance and qualification

Equipment compliance with engineering specifications directly contributes to nuclear safety and this is well managed. However, the progress of the qualification programme must be closely monitored. By mid-2024, only a third of the qualification summary reports (QSR) and quality preservation sheets (QPS) had been produced. Some manufacturing runs have been started before validation of the qualification files, but the project has identified the risks and they are well managed. I will continue to monitor this topic during my next visits.

Ensuring maintenance during operation

The maintenance resourcing model currently chosen for operation is based on a PWR benchmark but feedback from other EPRs has revealed the need to further evaluate the headcount. The Operator plans to supplement this in-house resourcing with long-term service agreements. This resourcing model potentially challenges EDF's standard practice, which usually provides a greater level of control of maintenance as part of its core activities.

HPC's technical specifications are moving in the right direction to benefit from the advantages of the EPR design, such as being able to carry out maintenance of a safety train with the unit in service, or unrestricted access to the reactor building service areas whilst at full power. I unreservedly support this approach, which facilitates operation while preserving nuclear safety. Establishing the in-service inspection requirements (list of welds and qualification of procedures) represents



Installation of unit 1 reactor vessel, HPC

a substantial workload that needs to be managed. The project has identified this challenge and is managing it effectively. I will be keeping a close eye on its progress.

Engineering on marching orders

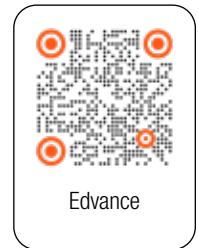
Edvance is carrying out the detailed design that has reached a satisfactory level of maturity. The end of the detailed design milestone was achieved in November 2023. CGN, the Chinese shareholder, considers the project more mature than it was in Taishan at the cold functional test stage.

The project's challenges are now focusing on the production of execution plans, the completion of civil engineering work, and the qualification and installation of equipment.

EPR E (EPR Engineering UK), the UK subsidiary of Edvance, was created in 2023. With a staff in excess of 800, it is gradually taking over the activities of its parent company and CNEPE, relying in particular on French expatriates. EPR E contributes to the Responsible Designer (RD) role for its two customers, HPC and SZC (Sizewell C), for the nuclear and conventional islands. This role is delegated by Edvance and CNEPE. They play a key role in design replication from one project to the next. To manage the workload, EPR E has created an engineering alliance with three partners and aims to sub-contract 40% of the work. The emphasis is on a 'consolidated design office' with 'work package' arrangements. Staff retention and increasing skills and expertise are major challenges for EPR E.

The Joint Design Organization of EPR E is located on the HPC site. This reactive organisation deals with any questions and minor non-conformities with the construction site teams. Access requirements, which prevent the site from being overwhelmed with visitors, should not impede the presence of EPR E engineers. I encourage EPR E and the project to identify a practical solution. Design changes are still numerous and are managed by a Configuration Control Board. Although they mainly concern documentary aspects, their impact may now be greater because of the advanced state of construction.

Nuclear Services (NS), a newly created entity within EDF Energy, pools engineering resources to support Nuclear Operations, as well as the HPC and SZC projects. NS has certain delegated responsibilities on behalf of its operator customers.





Engineering sequence training, Edvance

SIZEWELL C: REPLICATING HPC

From the outset, the SZC project chose to replicate the HPC design. This decision has been maintained. The only reasons for differences in design are the site's specific characteristics of the heat sink and the geology, as well as the proximity of Sizewell B (SZB). This proximity calls for a common approach to external hazards between the two sites.

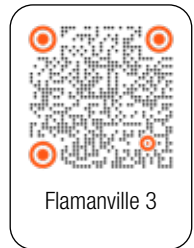
The project team has allocated itself the means to reach this ambition. The governance of the detailed design replication studies is structured with this in mind. The Office for Nuclear Regulation (ONR) is very supportive of this approach. The HPC and SZC projects benefit from the alignment of the organisation and people within the EPR E and NS support services and within the ONR and the Environment Agency. Replication is based on the HPC as-built plans and the supply chain is, as far as possible, identical between the two projects.

SZC and HPC are owned by two different companies. Replication will have to be rigorously maintained over time even if construction calls for more prefabrication at SZC, and obsolescence problems will have to be managed. The conditions of employment (employment contract, healthcare cover, etc.) are common to both HPC and SZC, which will facilitate the transfer of skills. Intellectual property issues must not hinder the exchange of information between the different licence holders. NS plays the role of integrator in this respect.

The EPR2 and SZC projects will run in parallel and are already working together. I encourage them to continue along this path, particularly in terms of project management tools, construction methods and the supply chain.

FLAMANVILLE 3 IN SERVICE

I am pleased with the start-up of FLA3, which is a just reward for the efforts of the project, operator and engineering teams. Fuel loading began in May, followed by divergence on 2 September 2024. Power raising and reactor tests are continuing, with commercial operation scheduled for 2025. During my visit in late 2024, I met motivated and committed staff who are conscious of the challenges.



A significant workload for the first full inspection outage

The programme for the first full inspection outage (VC1) is extremely heavy, equivalent to a first-in-series reactor upgrade programme. This VC1 must complete a number of major projects: replacement of the reactor vessel head and heat exchangers (RRI/SEC), major modifications to the I&C system, completion of weld stress-relief treatments, removal of temporary equipment, and completion of regulatory tests of the reactor coolant system (RCS) and reactor containment. The programme remains to be finalised and preparation for the outage must be accelerated. Once the start-up tests have been completed, it will be possible to determine the outage start date, as this depends on the fuel burn-up. The regulatory compliance dates for nuclear pressure equipment inspections, which could be incompatible with the outage start date, will have to be managed. A derogation arrangement can be envisaged.

I believe that staff dedicated to preparing the outage must be seconded as soon as possible. Staff (EPAT, EMAT) from the Central technical support entity (UTO) will greatly contribute to the success of this outage. Logistics will have to be coordinated with FLA1 and FLA2 outage activities.

The maintenance teams are encountering many difficulties. The ventilation systems represent a workload that is six times greater than that of the 900 MWe reactors. Many fire dampers are difficult to access, and their qualification period is short. Finally, on-line work management will have to quickly find its rhythm if it is to protect the resources allocated to outage preparation from disruption by real-time problems.

The general operating rules must be adapted

The site is experiencing some start-up problems with a number of nuclear safety events. These are inherent to calibrating the plant, the operator's familiarity with the plant, and the complexity of the general operating rules (RGE). Some events have a human factor component, while others result from the persistence of worksite practices incompatible with operation. Some of these events are also due to overly complex RGE, which are sometimes unclear and open to interpretation. Finally, some events are the result of persistent non-conformities in design or installation. Although OPEX from other EPRs has generally been incorporated, some events could have been avoided by more systematic and less siloed distribution of OPEX between Framatome's entities and its sub-contractors.

In consultation with the French safety authority (ASN), I believe it is all the more urgent to simplify the RGE, aligning them with the standards applicable to the rest of the operating fleet. We also need to ensure access to the reactor building service area is maintained during operation, a key feature of the EPR that is widely used by other operators. Today, this functionality is threatened by a very conservative method of assessing gaseous discharges that have no real impact on safety or the environment.

Ensuring new-build projects benefit from OPEX

The EPR2 and UK projects should fully benefit from start-up OPEX. The RGE must be mock-tested as soon as possible, and the radiation-controlled area must be commissioned so staff can develop the necessary behaviours much earlier than at FLA3. The final handover of operational responsibility from the project organisation to the Operator must take place at the latest when the fuel is loaded. Framatome must be better integrated into the project and provide immediate feedback on the EPRs in operation. Plant configuration management throughout the project up to handover must be subject to OPEX. Finally, the in-field experience of FLA3 operators should be used to support the EPR2 project during the detailed design phase: "*OPEX is people-orientated*". Successes should be sustainable. Improvements are needed with respect to the choice of certain equipment, their location, means of lifting, ventilation, reliability of electrical cubicles, and the motors for heavy doors, etc.

The HPC project has organised the secondment of staff to FLA3, and the contractual framework is defined by a technical service agreement. Preparatory training courses in French combined with AI technology will help overcome the language barrier, which should be fully exploited.

Continue the support for FLA3

The site benefits from a fleet support plan, which provides consolidated resources, helps to position the players, and offers methodological support for the preparation of VC1. In addition to advice and coaching, above all, it is the support from experienced staff that is most useful to the site.

Many 'open points' still need to be addressed by engineering. Not all of them will be resolved at the end of VC1, and others could be added to the list. Design teams from the Engineering and Supply Chain Directorate (DISC) will have to remain mobilised to support FLA3 and the DIPDE in the role of engineering for the operating fleet, after VC1.

An 'end-of-commissioning' document (DFD) is required for FLA3. This must take into account certain changes in the nuclear safety studies (including probabilistic safety assessments), as well as OPEX from operation and start-up tests. The fear is that the compilation of this document will resemble a safety review, with its potential batch of documentary and equipment modifications as soon as the reactor has started up. The content of this document will need to be well controlled, deferring all remaining subjects to the periodic safety review (PSR) that fall under its remit.

Making the most of the EPR family

In 2024, I visited the Olkiluoto 3 and Taishan sites which already operate three EPRs, and who appreciate their ease of operation. I found that the Finnish and Chinese operators use, to varying degrees, the specific features of the EPR design: access to the reactor building at full power thanks to the 'two rooms' concept, and, in Finland, maintenance during operation thanks to four safety trains (contrary to FLA3). I could see that the Taishan organisation deals efficiently with its preventive maintenance and work requests, thanks to experienced planners.

Although Taishan's RGE are simpler than those at Flamanville, they are still more complex than those in Finland. The Chinese safety authority is in favour of their development, with the aim of achieving greater operating flexibility and making the most of the four safety trains. There are still persistent problems with neutron flux variations and the reliability of the reactor's internal instrumentation. Countermeasures are in place and long-term solutions are being developed. I note that the origin of the core instrumentation unreliability is not yet fully understood. Finally, like other Chinese sites, Taishan is working on the development of dry storage for spent fuel, taking into account the difference in fuel assembly sizes.

I would like to encourage the three operators (FLA3, TVO and Taishan) to step up sharing their OPEX via the EPR Owner-Operator Group (EPROOG) to take full advantage of the EPR's potential. Staff

exchanges, such as sending a Chinese shift manager and safety engineer to FLA3, are a good illustration of this.

EPR2: LEARNING FROM FLA3

The EPR2 project is progressing satisfactorily. Following the publication of the decrees for the environmental authorisation and for the use of the public maritime domain, preparatory work began on the Penly site in the summer of 2024.

The robustness of the design process is a key success factor for the project. At the end of 2023, EDF decided to further develop the basic design of certain buildings. The maturity review in summer 2024 confirmed that the project was progressing well and gave the go-ahead for the detailed design phase. Design complexity will have to be managed properly, and the number of hazard scenarios limited to what is necessary.

The schedule for evaluation by the ASN takes better account of the project's industrial constraints. Agreement has yet to be reached on certain standards, in particular for fire and earthquake ([see Chapter 5](#)).

As the future Operator, the DPN has been involved in EPR2 project decisions for several years. They have expressed their needs which have been taken into account. However, the Operator joined the project too late, at a time when the main performance and nuclear safety options had already been largely defined.

A first version of the principles of the EPR2 RGE should be drawn up by 2027 and submitted to the ASN for assessment. It is crucial to phase in the future RGE approach launched by the fleet in operation so that the EPR2 can benefit fully from it ([see Chapter 2](#)). It would be unforgivable for the EPR2 Operator to start up the plant with RGE from the past.

The success of the EPR2 project relies on the proper integration of OPEX from FLA3. Beyond the design and construction aspects, the choice of equipment and instrumentation, as well as the architecture of the I&C system and the human machine interface (HMI), will have to preserve the strengths of the EPR design while correcting what can be improved.



Siting of Penly 3&4 EPR2 reactors

Preparations for the operation of the future EPR2 fleet will have to include talent pools, both within the in-service fleet and in the project teams. It will be essential to ensure, from the outset of the project, better integration between the project organisation and the operator, along the lines of the OneFla3 model, which was introduced too late. Digital continuity between the construction phase and the operations phase will have to be planned to ensure good plant configuration management. The future strategic plan for the DPN should include the EPR2 project.

RECOMMENDATION

In the context of a significant increase in the workload of the EPR2 programme, I recommend that the Director of the DISC allocate the necessary engineering resources to support FLA3 after VC1.

*Dampierre-en-Burly power station*

After many years of ‘nuclear bashing’, the trend is reversing, nuclear power is attracting renewed interest and new vocations.

The industry in France and the UK is mobilising to meet the challenges associated with new reactors and continued operation for the in-service reactors.

Framatome is investing in skills, as well as in its industrial facilities at the Saint-Marcel and Le Creusot sites.

Mobilising our industry partners

08

In France, where only 9% of the GDP is generated by the industrial sector (with a European average of around 15%), the Belfort announcement in 2022 committed to extend the life of the existing fleet and build new reactors.

The French National Council for Industry (CNI) coordinates the different industrial sectors, including the nuclear industry. The Strategic Committee for the Nuclear Industry (CSFN) defines the strategy in a sector contract, the update of which should be signed by the State in early 2025. Its implementation is guaranteed by the French Nuclear Energy Industrialists Group (GIFEN), the University of Nuclear Skills (UMN), the regional service provider agencies (ARP), and Nuclear Valley (R&D).

The UK has drawn up a 'Powering up Britain' roadmap to ensure its energy security and carbon neutrality by 2050, with a target of 24 GW of nuclear power.

STATE OF PLAY

Expectations of the French sector

The sector is waiting for the public authorities to legislate (*via* the multi-year energy plan), and ensure long-term visibility, continuity in commitments, financial support, and the development of skills in the education system. The sector's appeal and robustness depend on this.

Its main concerns are recruitment and engineering skills, accelerating EDF contracts to secure investment, more use of best-offers, and partnerships. The outlook for nuclear is still seen as fragile, with over-optimistic schedules.

The success of the French New Nuclear Programme (PNNF) involves developing the workload, recruitment drives and the professional development of newcomers, as well as the growth and modernisation of the industrial fabric of the tier 2 and below supply chain.

Improving attractiveness

The vocational crisis that we are facing, linked to profound societal changes, is affecting all sectors of industry. Career attractiveness is suffering from various constraints: isolated sites, spouse's employment, staggered working hours, limited working-from-home opportunities, and the burden of procedures. Elsewhere in regions such as Cotentin and the Loire Valley, full employment is putting the labour market under pressure.

Contractors are adapting to the trends of lower mobility and less acceptance of long-distance travelling by: opening branches close to the sites, recruiting locally (sometimes outside the industry), and training employees from scratch (particularly in welding). They are offering work-study apprentice programmes from secondary school upwards.

The UMN, in collaboration with the French national education system, is developing training courses. Yet they are struggling to fill these courses. Public education remains too far removed from needs, forcing manufacturers to make up for this lack by setting up their own training centres. I unreservedly support apprenticeships, which help to better understand the professions and provide useful training. However, the possibility of working in a nuclear power station is still hampered by a restrictive qualification system. At EDF SA, the recruitment rates at the end of the apprenticeship phase still seem too low, whereas they are higher at our partners.

GIFEN: the industry's association

GIFEN has set up a programme of operational nuclear excellence (PEON) to share experience and best practices, building standards of excellence, providing access to tools and training, and offering professional support. It has set up a safety quality commission and a programme for new entrants. GIFEN helps to ensure that technical standards and specifications are clear, explicit and meet the right needs. Its members are working to formulate the requirements for specifications that are compatible with current practices. GIFEN helps its members to consider these practices during the tender phase and AFCEN helps implement them.

United Kingdom: a sector under pressure

There is also a shortage of workers in the UK nuclear industry. Welding, electricity and certain specialties such as fire and human factors, etc., are the areas most under pressure.

Nuclear Operations relies on long-standing partners who are well integrated and treated as equals. However, the appeal of the sites over the last ten years has eroded. Our partners are finding it difficult to attract and retain qualified staff. The Covid pandemic has changed the way people consider their work-life balance, further reducing the availability of resources.

The scissor effect between inflation and the wage terms defined by the National Agreement for the Engineering Construction Industry (NAECI) for Nuclear Operations has led staff to leave for better paying projects (HPC, Rolls Royce SMR) or industries. These tensions are especially manifest at the Hinkley Point B site, adjacent to the EPR construction site.

Nuclear Operations guarantees the workload of its main partners, the Big 6, who have a long-term contract (lifetime enterprise agreement). A human resource retention plan was also initiated in 2021.

Regular reprioritisation of outsourced engineering activities throughout the year has resulted in a lack visibility and stability for the partners involved. More modern working methods, such as automated data extraction using AI, would increase the added value and appeal of the sector.

QUALITY ABOVE ALL

The operator is responsible for ensuring the quality of manufacturing, installation and maintenance at in-service plants. This must be able to rely on skilled, organised, well-informed and committed personnel to comply with the quality rules, requirements and specifications governing their activities.



Steam generator replacement, Blayais

ISO 19443: the nuclear standard of excellence

In 2018, Framatome and Bureau Veritas transformed their NSQ 100 standard into the ISO 19443 standard. It is not a substitute for other certifications. Reflecting the requirements of the INB ministerial order, it clarifies the quality requirements expected of suppliers in the nuclear sector and their supply chain. It applies to suppliers and sub-contractors, including products or services concerning the nuclear safety of power plants and fuel facilities (AIP). Reliability, traceability, skills and nuclear safety awareness are essential. The certification attests to the level of maturity of the quality management system. It distinguishes the ability of a supplier or sub-contractor to meet the requirements applicable to the activities of their clients in a nuclear facility. This standard should serve as a reference in international calls for tender.

Compliance with ISO 19443 has been integrated into the EPR2 project since 2019 and extended to our contracts in 2021 under the EXCELL plan. UTO, DCN and engineering departments who are in direct contact with suppliers have obtained their certification. I believe it is necessary to renew the DQI's certification and to consider that of the purchasing group of the Supply Chain Division (DSC).

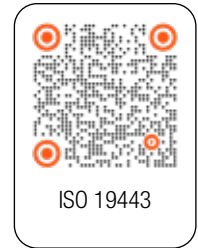
The feedback from our partners is positive, around 50% are certified. They feel that the standard provides real added value in terms of nuclear safety culture, traceability, reinforcement of requirements, and monitoring of their own supply chain. However, I note that their enthusiasm is waning. They regret that certification does not lighten the qualification and monitoring process. It will have to be adapted.

Tracking down irregularities to their source

The number of proven irregularities (counterfeit, fraudulent or suspect items, CFSI) is limited and comes from isolated acts. The foundry sector has difficulty complying with specifications. Sometimes irregularities are also observed in the traceability of maintenance activities.

Irregularities stem from a lack of knowledge, safety culture and compliance with regulations, or from financial or scheduling pressure.

In 2018, EDF implemented an action plan to strengthen surveillance to better prevent and detect irregularities, both in manufacturing and in operation. In 2020, the surveillance plans focused on an analysis 'by component' and 'by supplier' on the basis of a risk assessment. A specific CFSI project was set up within the DQI in March 2024. A new system for screening irregularities detected during inspections was put in place and all suspected irregularities are now examined by a dedicated unit. In his letter addressed to the ASN Chairman on



19 March 2024, Luc Rémont committed to strengthen EDF's action plan in this field.



Paper has taken precedence over technical skill

During my discussions, I have identified several improvement areas. In the event of suspected fraud, the judicial process blocks access to information, which delays feedback on nuclear safety. It also takes too long to resolve proven CFSI cases, averaging 3 to 4 years. In accordance with the INB ministerial order, non-conformities must be handled in proportion to the risk. In the foundry sector, it is crucial to improve the traceability of repairs carried out on cast components. The DPN and DQI procedures for informing the ASN in the event a suspected irregularity must be harmonised. Security protocols must ensure data authenticity and integrity. There needs to be convergence in approaches between Framatome and the ASN, without introducing excessive complexity.

MORE THAN JUST CONTRACTORS, THEY ARE PARTNERS

Standardising practices

During my discussions, I have measured the exasperation in the differences in practices between sites. They introduce confusion, complicate the tasks of those involved and affect all areas: industrial safety and PPE, radiation protection, fire, risk assessment, quality error reduction (NQME), foreign material exclusion (FME), lifting, application of human error prevention tools, contractual terms, and 'just culture' criteria.

Our partners feel that overly excessive documentation quality is counter-productive: *"paperwork takes priority over the technical task"*, e.g. a welder can sometimes only get half an hour of welding done in a day. Possible ways of simplifying the process include: using the inaugural meeting to review the prerequisites and adjust requirements to only what is necessary, reducing the number of EDF documents, and using customised service provision contracts that include worksite logistics.

Regional service provider agencies supporting our partners

Grouped into five geographical areas (IFARE, GIPNO, PEREN, GIM EST, GIE Atlantique), the regional agencies help their members to adapt to the specific requirements of the nuclear industry. A national agreement standardises practices. Their activities are coordinated by the DPN. The organisation of these agencies has found fresh impetus which needs to be maintained.

I would encourage these regional agencies to not just limit themselves to quality, health, safety and environment (QHSE) training; they should seriously engage in recruitment, development of skills with the UMN, and the modular preparation process for outages.

IFTEA

The technical and energy training institute (IFTEA in Ardèche) was set up by the employment skill group of the Cruas consultation committee (ICC) for the benefit of the fleet upgrade programme. As a technical platform and training centre, it meets the labour needs and expectations of EDF's partners. It has a training facility, which is used to train company employees and technical college students specialised in industrial control and automatic regulation.

Restoring customer-supplier relations

The DSC is taking over the EXCELL project. Renewal of customer-supplier relations is continuing thanks to the 'supplier development' and 'supplier recovery' quality improvement initiatives, which are appreciated by our partners. Contracts now include more 'best offers' to avoid mechanisms that drive prices down, sometimes offset by amendments to volumes and to changes in reference standards. EDF also wishes to narrow its range of suppliers to improve quality, while taking into account capacity risk with a view to continued operation.

Legislation is now in place so public procurement can be adapted to the specific characteristics of the nuclear industry: exemption to allow for work package allocation and longer time limits for framework agreements, option of using 'credibility' as an award criterion, and

the possibility of simplifying contract amendments during execution. Their correct use by EDF will allow our partners to improve quality by investing in staff skills and the content of their services.

The industrial policy of the in-service fleet operates on three different levels: national, regional and local. UTO develops industrial strategies with three focal points: specialised markets, general markets, and regional markets. Coordination with the Group's industrial policy is well ensured. The DPN's industrial policies have only recently been written, so care must be taken to find the right balance between centralisation and the preservation of know-how, particularly local innovations benefitting from 40 years of experience. Industrial policy managers at the sites who have a good knowledge of the local economy and the challenges of regional involvement, must work with the UTO segment managers. For specialised markets, under the auspices of START 2025, the DPN and its partners are working on skills. Qualification is now required for all sensitive work. I think these are good solutions for reducing maintenance rework.

Operating as an extended business

EDF aims to transform the way it works with its partners. The extended business is being deployed in new projects as well as in the existing fleet, which requires adapting the contractual framework and information exchange platforms.

There are all kinds of operating methods available to engineering, such as collective working in the form of 'mass' service contracts, or by work package arrangements. The cultural barriers associated with the risk of embedded contractors have gone. I think this is a strong move.

Adapting information systems is essential for working as an extended business because they do not communicate naturally. Facilitating the exchange of information and avoiding its reproduction elsewhere requires data-centric management rather sending pdf files.

The DPN's information system project is conducting experiments and aiming for quick wins, such as Phone Connect and eDRT, which have won the unanimous support of our partners.

The digital transformation of engineering and new-nuclear projects is driven by the Switch programme and its 3DX platform. Success will depend on high-quality data, a limited number of tools and effective collaboration between users. The Business Process & Data Owners (BPDO) are driving this initiative. The difficulties of the 3DX plant lifecycle management (PLM) software were only partially resolved in 2023. In 2024, stakeholders focused on three workstreams: strengthening customer/architect/publisher governance, bringing stakeholders together to better understand user needs, and implementing more frequent software version upgrades. The situation has improved, but user satisfaction remains below expectations.

Digitalised nuclear pressure equipment management

Following the difficulties in complying with the nuclear pressure equipment regulations (ESPN) during steam generator replacements, EDF launched the 'ESPN digital project' in 2018. The aim of this platform is to digitalise all the information required to obtain compliance certificates.

The tool centralises data and streamlines information exchanges between stakeholders, based on the extended business principle between manufacturers, operators, professional associations and qualified bodies (ONA). It facilitates the production of regulatory documents, consolidates the progress of issues, and includes mobile functionalities that can be used during inspections. The platform is accessible to the regulatory body. Currently being rolled out across the industry, its use will be extended to the EPR2 projects.

SPARE PARTS: A PERSISTENT SOURCE OF FRICTION

The consequences of the war in Ukraine, which could have threatened the supply of spare parts, have been well managed, with no disruption to supplies. However, in France, spare parts remain a source of friction and are the cause of postponed activities. The problem is complex and multi-faceted. Progress requires work on all fronts: quality of databases, stock (and its documentation), ordering and targeting needs. The mechanism for reserving spare parts is not sufficiently virtuous; the logistics section is unnecessarily blocked by volumes, breakdowns, and orders for made-to-order parts that are eventually not used. The importance of site logistics managers (Rlogs) should be strengthened by the appointment of senior-level maintenance profiles.

'End-of-life' stocks and repairs are a mitigation for obsolescence. Technical monitoring is provided by I&C equipment ageing oversight committee (OVCC), which is working well, but the electrical equipment ageing oversight committee (OVME) needs to be revived as a matter of urgency. Some storage capacities are reaching their limits, such as for equipment less than 10 tonnes that requires handling by overhead cranes.

Spare parts associated with plant modifications are even more problematic, and from now on, they will be ordered at the same time as the equipment. There is still the legacy of old plant modifications to process.

Generally speaking, I feel that UTO's spare parts department is proactive, supporting the nuclear power plants, and works with the ASN to deal with their problems and any CFSI emergencies in a timely manner.

In the UK, the main issue is obsolescence. Strategies include building up stocks (lifetime purchases), repairing or re-engineering original parts. As plant lifetimes are extended, it is essential to check that stocks are sufficient, particularly for the fuel route and internal electrical supplies.

FRAMATOME: GATHERING MOMENTUM

Regaining industrial control

In a context where resources were being prioritised to deal with SCC repairs, the replacement of the steam generators at Flamanville in 2023 was impacted by difficulties in mobilising resources, skills, scheduling and managing quality non-conformities. The replacement of sections of the safety injection system at the Chinon plant experienced similar difficulties in 2023.

The installed base business unit is being consolidated in preparation for the replacement of steam generators and primary cooling system elbow joints scheduled from 2026 to 2028. Skills remain a major challenge due to the retirement of experienced staff. Regaining control of activities began with the Cruas 3 steam generator replacement, which EDF and Framatome chose as a priority for 2024. They gave themselves the means to succeed, having worked together for the past three years. The historic 2009 contract, which did not satisfy either party, has been amended to make it more realistic. The working methods now enable interfaces to be managed more effectively, prefabrications are anticipated, activity planning takes into account the availability of Framatome resources, worksite preparation is linked to modular planning, the steam generator replacement schedule is integrated into the site's project management tool, and management and reporting have been improved.

Framatome invests in its plants

Buoyed by its order book, the Saint-Marcel and Le Creusot plants are investing heavily in their facilities and skills.



Saint-Marcel

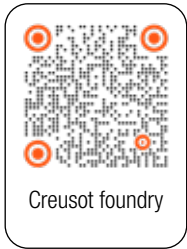
Saint-Marcel is extending and reorganising its production line. To improve quality, it is developing new working methods: quick response quality control (QRQC), frequency rate indicators, linking production to specifications to ensure they are realistic, workflow operation by specialised workstations, a short feedback processing loop, increased robotics, product standardisation, and technology readiness level (TRL) reviews.



Forging operation at Framatome's Creusot foundry

The Creusot factory has overhauled its processes. Greater standardisation is improving quality and has reduced the number of non-conformities by 90%. With a view to autonomy, it will soon be internalising the production of reactor vessel internals in a new workshop (INOX).

In 2021, the DTI opened the Bourgogne calculation centre (CCB). Located at Saint-Marcel, it brings manufacturing and engineering closer together. Calculation-based substantiations are carried out in parallel and as close to the field as possible. The quality and production deadlines for substantiation notes have improved significantly.



Creusot foundry

Jeumont Mécanique is finding it difficult to meet its manufacturing deadlines. The industrial capacity is being affected by the design office's difficulties to supply the workshop and to manage nuclear pressure equipment regulations. A supplier recovery initiative has since been launched and has started to bear its first fruit.

RECOMMENDATION

I recommend that the Directors of the DISC and DPNT simplify the qualification system and the surveillance arrangements for our contract partners depending on whether they have obtained ISO 19443 certification or not. The objective is that our partners obtain certification.



Trying to predict the future and the challenges ahead is a complex exercise. When it comes to safety, there will always be solutions to the inevitable technical issues and financial constraints, but human and organisational factors will be difficult to resolve if neglected or not sufficiently anticipated. Safety depends on it.

Challenges for nuclear safety

09

CHALLENGES AND FOOD FOR THOUGHT

Our society is undergoing profound changes, which present us with as many challenges as they do opportunities. Society's expectations in terms of sustainability, the environment, work-life balance and absolute risk management are constantly increasing.

The EDF Group is no exception in its response to its own specific issues: an ambitious industrial programme; uncertainty on the lifespan of existing plants (with nearing deadlines for the AGRs); the capacity of new nuclear to take the baton on managing schedules and costs; a wall of investments in a context of financial fragility; development and competition of renewables, lack of alignment in Europe, unbridled international competition, etc.

Faced with these evolutions, our nuclear facilities, built at the end of the last century, our very hierarchical organisations, our historical culture marked by the quest for compliance with the prescribed, are being challenged.

Challenges common to both sides of the Channel could have been the subject of this chapter: climate change, re-industrialising and securing our national supply chains, economic and political instability, health & safety risks that will inevitably disrupt our societies. However, in a world faced with new technologies, we have decided to deal with human and organisational challenges in this chapter, and for which we believe we still have the 'upper hand' for the benefit of nuclear safety.

Far from being peremptory, our aim is to ask questions and explore new ideas so everyone will find an answer best suited to their objectives and environment, reflecting one of the principles dear to the philosopher Edgar Morin: "*Think globally and act locally*".

I remain convinced that, together, we must develop appropriate solutions to preserve nuclear energy as a source of sovereignty and independence, a driving force behind our economic development and a guarantee of environmental protection. Only this can give meaning to the individual and collective commitment of all stakeholders in the industry, and thus meet the high generational and societal expectations associated with working in a high-risk and complex industry.

Maintaining know-how and developing skills remain the prerequisite conditions for solving these complex equations.



The Aquarius fresco, Cruas



SAFETY IN THE FACE OF GENERATIONAL AND ORGANISATIONAL SHIFTS

The 1990s and 2000s were marked by a deterioration in how nuclear energy was perceived, with a loss of appeal for the sector in the face of pernicious dogmatism and the political influence of ecologist movements. Also, If you add the rapid de-industrialisation of Europe and generational turnover, the sector lacks experience and resilience (*see 2023 report*).

The renaissance of nuclear power as a response to the climate emergency means building new power plants and extending the service lives of existing fleets. This poses two challenges that are inextricably linked to nuclear safety, one technological and the other human.

RETHINKING OUR ORGANISATIONS

The design, construction and operation of new power plants calls for a massive increase in the industry's workforce. Far from the historical model of employers being able to select the best candidates and impose their conditions, the market is now unbalanced in terms of supply and demand, putting candidates in a position of strength.

Our organisations have been relatively stable in terms of tools and working methods, they are highly segmented, hierarchical, lack clarity, have become increasingly complex and lost efficiency. At the risk of also losing loyalty and allegiance to the company, they will have to adapt to the arrival of a new generation which will change the age and experience pyramid and will manifest different ambitions and expectations. Management and leadership models, and working methods will have to be overhauled to incorporate new technologies and digital technology if we intend to recruit and retain the best talent and make the most of their skills.

GETTING CLOSER TO THE FIELD AND IMPROVING EFFICIENCY

In a global world perceived as more accessible and simpler, the erosion of responsibilities and the increasing complexity of our organisations, processes and procedures are discouraging younger generations, who are keen for simplicity, information and autonomy. Criticised as belittling and excessively restrictive, the traditional framework is proving counterproductive.

The pandemic, with its health and social impacts, demonstrated our ability to quickly adapt our working models and methods. Although we only seem to have retained working from home, this period enabled us to re-focus on the essentials: the plant and the people. By limiting meetings to what was strictly necessary, we improved our margins by focusing on efficiency in the field.

Will we have to wait for another crisis before we can turn this around?

REASSESSING OUR METHODS OF LEARNING

The traditional methods of training, apprenticeship and knowledge transfer have proved their worth. They need to evolve and be more appealing to new generations, therefore better adapted to skill acquisition.

Our ambitions, such as choosing between 'doing it or having it done', must meet the aspirations of the new generation, who want to practise their profession in the field, a key component of a rewarding career path. Rather than getting caught up in administration, processes and documentation, they want to return to the technical aspects.

Our leaders and managers must also change their management methods, by promoting collaboration and building trust. By restoring

a sense of meaning to the job, and by advocating high standards, the transfer of knowledge between generations will happen naturally. Apprenticeships and mentoring can contribute to this.

BEING READY TO ACCEPT RESPONSIBILITY RATHER THAN AVOIDING IT

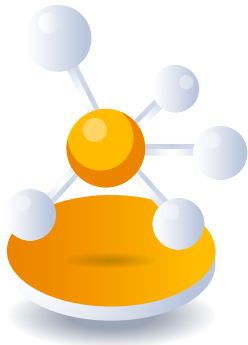
Another consequence of current work and management practices is a reluctance to take on responsibility. The reasons given for this are the increasing number of administrative constraints, complexity and pressure, the imbalance between professional and private life, with the feeling of 'living to work' rather than 'working to live', the lack

of recognition, and the fear of failure. We are at risk of discouraging people from taking on responsibility and, worse still, of being forced to promote those who do not have the capability. Giving back room to manoeuvre, valuing authority, rediscovering a taste for success, etc. are just some of the avenues open to us.

Although the nuclear industry is unique, the challenges it faces are not specific to it. Other industries have had to show versatility in order to adapt and evolve in a rapidly changing environment. What lessons can we learn from them?



Taking a water sample from the nature reserve lake, Blayais



SAFETY IN THE FACE OF COMPLEXITY

TRACK DOWN UNNECESSARY COMPLEXITY

A nuclear reactor and its operation are complex and will always remain so. We must try to find what can be simplified, through reactor design (e.g. core cooling without the worry of returning to criticality) or through IT tools (e.g. real-time representation of physical phenomena). Even more important, we need to overcome the unnecessary, harmful and even prejudicial complexities that have been building up in successive layers over the years:

- Proliferation of documentation, risk analyses, demonstrations and modes of proof
- Overdevelopment of processes, regulations and requirements
- Multiplication in the number of hierarchical levels, committees and signatures.

Nuclear safety demands reports, written rules, procedures, processes and traceability. But their excess is detrimental. Cognitive capacities are taken up, the meaning of words seems lost, doing work requires so many preconditions that enthusiasm and effectiveness are exhausted. The reality of action is replaced by the feeling of feeding a bureaucracy. Controlling the mechanisms that lead to increasing complexity is a priority.

MORE RESPONSIBILITY THROUGH A LESS CONTROL-ORIENTATED SYSTEM

The mechanisms generating complexity are systemic, both internally and externally. Often initiated by commendable intents, these mechanisms have many causes, including the expansion of organisations, the development of reassurance mechanisms, or the abuse of the concept of safety demonstration. At the same time, excessive wordiness and jargon is complicating our relationship with the world.

The growth of organisations fragments responsibilities and multiplies interfaces, processes and committees. Overcoming this state of disorder requires considerable energy, sometimes to the point of discouragement.

Too many quality issues have led to a proliferation of reassurance mechanisms to prevent them from happening again. This process seems to have gradually evolved into a requirement for total control from headquarters. Like the rest of society, nuclear safety is becoming increasingly more litigious in nature. Ultimately, it seems to be based on the belief that a system of rules, procedures and controls can replace professionalism, skills and discernment. Controlling everything means adding rules to rules, by trying to exhaust reality, which they never do. They also end up being contradictory.

The illusion of total control is reflected in the abuse of the term 'safety demonstration', which seems to have replaced safety itself (equipment important for safety have become 'equipment important for demonstration'). Starting with the INB ministerial order, it has replaced the terms safety case, safety analysis, safety assessment, etc. Its use becomes harmful when it implies that everything can be anticipated, that the scope of 'events' and the catalogue of foreseen events can be extended infinitely. We seem to have forgotten the lessons from Three Mile Island.

"PROFESSIONALISE STAFF INSTEAD OF REFINING STRUCTURES AND PROCEDURES"

Reducing complexity assumes fighting the illusion of total control. We need to take back responsibility and ask for more in-field training, practice, exercising of judgement, and making and taking responsibility for decisions. This means giving people the leeway to do so, while refraining from overwhelming them with other demands. In short, it

means agreeing to relinquish some control in favour of working on skills, understanding equipment, phenomena and risks, understanding the 'job', commitment and responsibility. This means being careful not to add layers of reassurance at the slightest error.

This requires skill, certainly courage, but also a certain paradigm shift. Many factors contribute to nuclear safety. But it is not necessarily a reason for incorporating them all into the general operating rules (RGE). Periodic tests in the RGE will never say everything about equipment availability. Routine maintenance, in-depth inspections, good operating practices, tests and rounds are all necessary. In short, it takes skills, professionalism and judgement.

Nor is everything a matter of traceability and modes of proof. We cannot judge and certify everything, from headquarters, about the way people work. We need to re-establish the principle of subsidiarity and restore the role of managers in the field, who monitor technical skills, practices and behaviour. It is all about assessing work situations.

Various avenues for progress should be explored:

- Going back to basics, i.e. focusing on the meaning, overriding factors, priorities

- Enjoying being in the field, seeing the equipment and the people, understanding work situations
- Talking to each other clearly, which includes voicing 'what goes without saying'
- Redefining what should and should not be considered as operating rules, and reviewing the real meaning of 'safety demonstration'
- 'Preparing to be unprepared', so as to be able to deal with the unexpected.

To this end, we can draw inspiration from Jean Bourgeois: "Any action must be based on the simple idea that it is ultimately the operator himself, managing its facilities, on whom safety will depend; it is therefore at this level that action must be taken, and this action will be all the more effective if it helps the operator to do their job properly, rather than complicating their task."

In short, it is a question of prescribing fewer requirements and demonstrating more rigour. This is the condition for building trust.



Electrical installation activity, HPC



SAFETY IN THE FACE OF DESIGN AND ENGINEERING

THINK OF THE USER

The EDF Group's engineering department has to design new user-orientated reactors in a highly restrictive regulatory context that does not make it any easier. How can we take advantage of the integrated nature of the EDF Group, which combines design engineering, manufacturing of large components, system architecture, and operation of the world's largest nuclear fleet, representing 2,000 reactor years?

The operator must clearly specify its needs. They are the only ones who understand the context in which the facilities are operated, and who have all the OPEX at their disposal.

Thinking 'user' means simplifying day-to-day operation in normal, disrupted, incident and accident conditions. Preventing errors and facilitating operation means ensuring easy access to information and controls, and simplifying operating procedures.

A design that accumulates calculation conservatisms and introduces an unreasonable level of sophistication in order to comply with the safety case could only be considered operable by its designer. The operator must benefit from optimal conditions to enable management of complex situations. The design must be accurate and relevant: knowing the risks in order to define countermeasures, limiting the number of components to what is necessary, designing automatic systems and control display screens that allow complexity to be understood and offer a simple representation of the facilities and physical phenomena.

Workers must be able to access, operate, inspect and carry out corrective and preventive maintenance on the equipment under the right conditions. In the control room, the operator needs easily

interpretable, comprehensive information to serenely monitor and control the facility. The control room operator must be able to manage difficulties in a proportionate manner.

Searching for information and formatting data so it can be used to diagnose and monitor the facility must be made easier. Automatic systems and controls must be designed for rapid, well-managed action.

Control room operators must be relieved of all unnecessary and thankless tasks, without losing awareness of the reality of the plant, and while maintaining their ability to control the plant in the event of a fault.

PROTECTING MARGINS

The plants must have sufficient margins to cover increasingly long service lives, to manage obsolescence, to deal with non-conformities, and to handle changes due to global warming or contextual evolutions (grid and generation mix). Design margins must be managed and maintained throughout their service lives.

Plants must be resilient in order to give the operator time in a context of increased 'mental load'. In complex situations, it must be possible to establish a diagnostic serenely, and action times must be calculated with margins ('operator margin'). Rapid kinetic scenarios must be minimised.

The choice of using a technology that can evolve allows us to refine legacy designs and thus benefit from OPEX. It also means doing more of the same, particularly with active systems. In the future, could we diversify our approach by introducing more passive features while controlling the risks inherent in passive systems?

SPECIFYING WHAT IS STRICTLY NECESSARY WHILE MEETING INDUSTRY STANDARDS

The specifications particular to the nuclear industry are sometimes too complex for suppliers to assimilate. Our specific requirements have distanced us from the products and processes of the industry responsible for manufacturing high-quality equipment in series. To maximise the transferability of our electronic equipment, to be more resilient to obsolescence, and to limit non-conformities thanks to products that benefit from a quality system adapted to large production runs, we need to design and specify what is strictly necessary, limit the number of catalogue references and close the gap with industrial standards. Involving our suppliers in our engineering phases will contribute to this.

EMBODIMENT OF THE NUCLEAR SAFETY CULTURE

The principles of a nuclear safety culture apply just as much to design as to operation. This is a challenge for an engineering distanced from a plant that will be put into service a long time after its design. The fragmentation of tasks, coupled with the pressure of meeting the

project milestones, can lead to inhibiting the level of technical rigour required, as in case of the Boeing 737 Max.

How can we always make nuclear safety the overriding priority and embody this? Everyone is involved. Engineers and experts must work together, demonstrate a questioning attitude and challenge their own practices. Engineering judgement must be developed by hands-on knowledge of facilities to enable good design, maintain a sense of balance and order of magnitude, and refocus on what is necessary. Managers need to be committed and exemplary. A proportionate allocation of resources, a commensurate level of professional development, and the right level of requirements must be guaranteed.

How can we ensure that engineering has a management system that provides a good level of nuclear safety culture? The areas to focus on are sharing of information between engineering departments, identification and handling of non-conformities, continuous learning that truly incorporates feedback, self-assessment, and comparison with international practices, etc.



Lifting activity, Cruas



SAFETY IN THE FACE OF DIGITAL TECHNOLOGY AND ARTIFICIAL INTELLIGENCE

After a century of industrial revolution which has seen the conquest of space and control of nuclear energy, the end of the 20th century has been marked by a major evolution: the digital revolution, which has rapidly permeated all aspects of our societies, without being able to measure all its effects in advance.

This transformation has been marked by the widespread use of computers, networks, the Internet, smartphones, tablets, 'clouds', and other data centres. It has radically changed our organisations and working methods, our relationship with time and our ability to reason, and has facilitated the consumption of information and the sharing of knowledge. The digital revolution took place in just a few decades on an exponential scale.

Without being sure we have mastered the digital revolution yet, are we ready for that of artificial intelligence (AI) and machine learning (ML)? Will machine intelligence help us to prevent natural human error? What place must we give to human beings?

TAKE THE BEST PART OF AI

The ability of a machine to help humans solve complex problems means that it learns and improves on its own. The first examples of this can be found today in autonomous cars, which beyond modelling roads and signs, assess the behaviours of good and bad drivers that they encounter. AI is therefore not only an augmented version of the world around us, which represents a vast quantity of data, it is an attempt to create an augmented version of man through his ability to produce answers, logic and reasoning.

In our role as an Operator, the prospects are manifold. Powerful in compiling, storing, analysing and processing data, AI contributes to fundamental research and technological innovation from the outset, then facilitates the operation of systems and reduces the cost of

ownership. In the future, AI applied to predictive maintenance will, at the same time, enable optimising equipment availability, improving reliability, and saving time, human and financial resources. By making better use of weak signals, it will facilitate feedback and the processing of considerable data gathered by the fleet. By freeing up time-consuming tasks, it can encourage more interaction, and therefore the discussion of ideas and the collaborative resolution of complex problems.

CONSTRAINED BY STANDARDS OR OPENING THE SCOPE OF POSSIBILITIES?

As of 2026, the European Union AI Act will come into force to regulate the use of this technology in a number of areas using a risk-based approach. It will stipulate graduated obligations for all parties involved in the AI value chain according to the level of risk associated with each use of AI.

It is crucial, however, not to shackle innovation too much through standards, at the risk of either killing it or seeing it smuggled in. On the contrary, it is important to give free rein to initiatives by enabling their use as much as possible without being inhibited by the 'zero risk' principle. Then, before wide-spread use, the innovation must be screened by an assessment grid to ensure that it has the right impact on safety and the right place for people.

Aware of its potential, the International Atomic Energy Agency (IAEA) has taken the lead by launching an online platform entitled 'AI for Atoms'. It organises interdisciplinary forums where professionals can exchange ideas and collaborate more effectively on AI in nuclear applications, science and technology. The EDF Group, like many industrial companies, is developing projects, some of which aim to improve nuclear safety (transport, material control, radiation protection, etc.). From these first application building blocks, we need to ensure

that human intelligence remains the driving force behind AI, machine learning (ML), big data, and the Internet of Things (IoT).

TAMING AI TO THE BENEFIT OF NUCLEAR SAFETY

The risks associated with the development of AI are real: removing humans from the decision-making process or substituting certain human actions with AI in the belief that they will be secure. The risk would then be to progressively lower the level of expectations and the ability to think, understand, decide and even, ultimately, act on one's own.

How can we use this technology wisely? The challenge is enormous. More than ever, its domestication demands ethical rigour: far from

replacing humans, AI must assist them without depriving them of their critical judgement, their own experience, their intuition or their creativity. This domestication also requires technical means to ensure data protection, detection of algorithmic biases and good cyber hygiene to counter the effects of computer failure, whether malicious or not.

Beyond technology, we also need to make this cultural revolution a success. To improve performance without compromising safety, collective awareness and significant training are necessary.

The digital culture is inseparable from the nuclear safety culture, which needs to embrace and value the digital transformation that is now upon us.



Dampierre-en-Burly power station



SAFETY IN THE FACE OF INDIVIDUAL AND COLLECTIVE REQUIREMENTS

The increasing importance of energy challenges, the struggle to win back performance, the obsessive quest for ‘zero error’: these are hallmarks of our industry, which are placing ever-increasing demands on the men and women who design, build and operate our reactors.

Being a good professional is increasingly multi-faceted: it is necessary to be skilled, comprehend standards, know organisations, respect work processes, ensure our actions are reliable, carry out suitable checks, take into account feedback, deal with the unexpected, make decisions at your own level, but also know how to seek support appropriately. The same is true at all levels of the organisation, including management positions, where the increased responsibilities can even exacerbate the symptoms. In response to this trend, a number of opposing phenomena are emerging: fear of failure and avoiding responsibilities for some, a form of over-commitment and compensation that can lead to exhaustion for others. How can these problems be resolved on a deeper level? How can we find a better balance?

FOCUSING ON THE INDIVIDUAL IS NOT ENOUGH

Solutions centred on the individual or the organisation should not be overlooked. Investing consistently in training, defining a better division of roles, providing support and coaching are all avenues that have already been explored and should be pursued. However, are these solutions now showing their limitations? The cognitive limits of the individual, including the brain and its mechanisms, are by nature finite. The limits of ‘everything being processed’, where the temptation to regulate human interactions through even more regulation leads to a de-sensitisation to risk and kills spontaneous collaboration.

Frequent reorganisations requiring so much energy and rarely capable of addressing the real problems, are showing their limits. Isn’t part of the truth to be found elsewhere? Must we change our methods and give more room to collective efforts? At the same time, must we re-learn how to talk to each other and rediscover what cooperation actually means?

INVESTING IN THE COLLECTIVE

Work is rarely done alone; it is naturally collective and collaborative. At a time when individuals risk being left to their own devices in increasingly complex organisations, the feeling of being part of a working group or team can be a real stimulant. A factor of integration, a collective welcomes newcomers and shares its rules and know-how with them.



Beyond the simple feeling of belonging, many human factor specialists believe that *“the vitality of groups is a prerequisite for safety”*. By helping to identify at-risk situations not covered by procedures, and by sharing its experience and the skills of its members to manage unforeseen situations, the collective is a major factor in defence in depth. A well-functioning team is more than just the sum of its parts: it tests ways of doing things and selects the best ones.

Strategies designed to give the professions a more prominent place than processes, the introduction of communities of practice, and regular management team meetings: these are all examples that illustrate this approach.

MAKING THE LEADER THE IMAGE OF THE COLLECTIVE

What are the conditions for creating teams that work well? Occupational psychologists stress the importance of creating a culture of 'psychological safety' (Amy Edmondson) where everyone feels confident enough to express their doubts and share their questions. In this context, leaders have a particular responsibility to establish a climate of trust and mutual respect.

This idea of working at team level and beyond is also promoted by WANO, which includes it as one of the five nuclear leadership effectiveness attributes: 'Create an environment of teamwork, trust and cooperation'. In these expectations, WANO stresses the key role of the leader in creating the right conditions for everyone to feel they have a stake in the team's performance and encouraging cooperation at all levels of the organisation.

A lack of cooperation is particularly noticeable at sites in difficulty. In such situations of under-performance, individual teams and departments will have a natural tendency to withdraw into their 'collective', seeking to preserve their own function or even pass the blame on to others. It is management's primary role to remove barriers and rediscover the pleasure of working together. Such contexts highlight, often too late, the importance of working in 'periods of calm' to create shared values.

Leadership reveals the potential of a team and is a legitimate driving force towards a shared objective of performance and a guarantee of safety.



In-field knowledge transfer, Hinkley Point B



Flamanville 3 power station

Appendices

RESULTS FOR THE NUCLEAR FLEET

EDF SA
EDF ENERGY

KEY DATES FOR THE NUCLEAR UNITS

EDF SA
EDF ENERGY

THE NUCLEAR SITES

EDF SA
EDF ENERGY
FRAMATOME

TABLE OF ABBREVIATIONS

RESULTS FOR THE EDF SA FLEET

N°	Indicators	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor ¹	1,16	0,98	1,12	1,28	1,45	1,4	1,3	1,4	1,2	0,9
2	Number of significant nuclear safety events (0 or greater on INES) per reactor ¹	10,03	9,78	11,59	12,6	12,7	12,4	12,9	12,2	12,7	12,6
3	Number of significant events per reactor • Non-compliance with technical specifications • Reactivity	1,24 -	1,48 -	1,41 0,9	1,69 0,7	1,8 0,9	1,5 0,6	1,5 1,0	1,5 0,7	1,1 0,7	1 0,7
4	Number of alignment errors ² per reactor	1,74	1,64	1,78	1,24	1,4	1,3	1,1	1,3	1,32	0,98 ⁶
5	Number of trips per reactor (for 7,000 hours of criticality ³) • Automatic • Manual	0,66 0	0,48 0	0,38 0,04	0,31 0	0,53 0,03	0,29 0,04	0,53 0	0,36 0,02	0,32 0,04	0,54 0
6	Average operational collective dose per nuclear unit in service (in man-Sv)	0,71	0,76	0,61	0,67	0,74	0,61	0,71	0,67	0,72	0,75
7	Exposure of individuals: • Number of individuals with doses above 20 mSv • Number of individuals with doses between 16 and 20 mSv • Number of individuals with doses between 14 and 16 mSv	0 0 2	0 0 1	0 0 0	0 0 1	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0
8	Number of significant radiation protection events	109	117	131	170	171	173	108	140	141	108
9	Availability (%)	80,8	79,6	77,1	76,5	74	71,9	72,9	58,1	67,3	74,15
10	Unplanned unavailability (%)	2,48	2,02	3,26	3,7	3,95	5	4,55	2,36 ⁵	3,69 ⁵	3,9
11	Occupational accident rate Tfg (per million hours worked) ⁴	2,7	2,8	2,2	2,3	3,3	2,9	3	3,1	3,1	3,6
12	Occupational accident rate LTIR (per million hours worked) ⁴	-	-	-	-	2,4	2,2	2,2	2,0	2,0	2,0

¹ Excluding 'generic' events

² Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event (statistical data reviewed in 2018)

³ Average value for all reactors, excluding external causes, unlike the WANO parameter which is based on the median value

⁴ Accident rate for EDF SA and its contractors

⁵ Data doesn't include CSC (8,3% in 2022 and 4,18% in 2023, CSC included)

⁶ Undefined data and extrapolated from the results at the end of October 2024.

RESULTS FOR THE EDF ENERGY FLEET

N°	Indicators	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor ¹	0,47	0,27	0,47	0,53	0,27	0,07	0,47	0,13	0,27	0,27
2	Number of significant nuclear safety events (0 or greater on INES) per reactor ¹	7,4	10	6,13	5,93	6,73	5,47	6,2	5,53	5,27	4,73
3	Number of cases of non-compliance with technical specifications per reactor	1	0,8	0,6	0,6	0,67	0,87	0,53	0,6	0,47	0,47
4	Number of alignment errors ² per reactor	2,87	3,13	0,93	1,67	1,67	1	1,33	1,2	1,47	1,07
5	Number of trips per reactor (per 7,000 hours of criticality ³) • Automatic • Manual	0,57 0,19	0,3 0,42	0,49 0,37	0,89 0,20	0,56 0,32	0,35 0	0,63 0,27	0,49 0	0,23 0,12	0,12 0,24
6	Average operational collective dose per nuclear unit in service (in man-Sv) • PWR • AGR	0,048 0,067	0,544 0,021	0,296 0,02	0,096 0,05	0,255 0,032	0,031 0,013	0,383 0,012	0,028 0,015	0,719 0,014	0,309 0,013
7	Exposure of individuals: • Number of individuals with doses above 20 mSv • Number of individuals with doses between 16 and 20 mSv • Number of individuals with doses between 14 and 16 mSv	0 0 2	0 0 1	0 0 0	0 0 1	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0
8	Number of significant radiation protection events	18	20	10	23	28	26	29	18	19	8
9	Availability (%): • EDF Energy fleet • PWR • AGR	77,3 100 73,7	83 82 83,1	81,6 83,8 81,2	76,1 89,4 74	65,8 80,6 63,5	61,7 99,4 55,9	60,4 64,2 59,7	77,9 98,7 73,1	73 73,7 72,8	72,7 84,6 69,6
10	Unplanned unavailability (%): • EDF Energy fleet • PWR • AGR	2,3 0 2,7	5,1 0,1 5,8	5 0 5,7	3,1 2,2 3,3	4 0,2 4,7	5 0,6 6,2	12,3 0 14,3	4,8 1,3 5,9	4 0,6 4,9	12,1 0 15,3
11	Occupational accident rate LTIR (per million hours worked) ⁴	0,4	0,3	0,2	0,5	0,3	0,3	0,3	0,5	0,3	0,8
12	Occupational accident rate TRIR (per million hours worked) ⁴	0,6	0,7	0,4	1,1	1,0	0,7	0,5	0,8	1	1

¹ Excluding 'generic' events (ones due to shortfalls in design)² Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event³ Average value for all reactors, unlike the WANO parameter which is based on the median value⁴ Accident rate for EDF Nuclear Generation and its contractors

KEY DATES FOR THE EDF SA NUCLEAR UNITS

Year in service	Nuclear unit	Power in MWe*	VD1	VD2	VD3	VD4
1977	Fessenheim 1 CP0	880	1989	1999	2009	N/A
1977	Fessenheim 2 CP0	880	1990	2000	2011	N/A
1978	Bugey 2 CP0	910	1989	2000	2010	2020
1978	Bugey 3 CP0	910	1991	2002	2013	2023
1979	Bugey 4 CP0	880	1990	2001	2011	2020
1979	Bugey 5 CP0	880	1991	2001	2011	2021
1980	Dampierre 1 CP1	890	1990	2000	2011	2021
1980	Dampierre 2 CP1	890	1991	2002	2012	2022
1980	Gravelines 1 CP1	910	1990	2001	2011	2021
1980	Gravelines 2 CP1	910	1991	2002	2013	2023
1980	Gravelines 3 CP1	910	1992	2001	2012	2022
1980	Tricastin 1 CP1	915	1990	1998	2009	2019
1980	Tricastin 2 CP1	915	1991	2000	2011	2021
1980	Tricastin 3 CP1	915	1992	2001	2012	2022
1981	Blayais 1 CP1	910	1992	2002	2012	2022
1981	Dampierre 3 CP1	890	1992	2003	2013	2023
1981	Dampierre 4 CP1	890	1993	2004	2014	2024
1981	Gravelines 4 CP1	910	1992	2003	2014	2024
1981	St-Laurent B1 CP2	915	1995	2005	2015	2025
1981	St-Laurent B2 CP2	915	1993	2003	2013	2023
1981	Tricastin 4 CP1	915	1992	2004	2014	2024
1982	Blayais 2 CP1	910	1993	2003	2013	2023
1982	Chinon B1 CP2	905	1994	2003	2013	2023
1983	Blayais 3 CP1	910	1994	2004	2015	2024
1983	Blayais 4 CP1	910	1995	2005	2015	2025
1983	Chinon B2 CP2	905	1996	2006	2016	2026
1983	Cruas 1 CP2	915	1995	2005	2015	2025
1984	Cruas 2 CP2	915	1997	2007	2018	2027
1984	Cruas 3 CP2	915	1994	2004	2014	2024

VD1: First ten-yearly inspection outage
VD2: Second ten-yearly inspection outage
VD3: Third ten-yearly inspection outage
VD4: Fourth ten-yearly inspection outage

Year in service	Nuclear unit	Power in MWe*	VD1	VD2	VD3	VD4
1984	Cruas 4 CP2	915	1996	2006	2016	2026
1984	Gravelines 5 CP1	910	1996	2006	2016	2026
1984	Paluel 1 P4	1330	1996	2006	2016	2026
1984	Paluel 2 P4	1330	1995	2005	2018	2026
1985	Flamanville 1 P4	1330	1997	2008	2018	2028
1985	Gravelines 6 CPY	910	1997	2007	2018	2028
1985	Paluel 3 P4	1330	1997	2007	2017	2027
1985	St-Alban 1 P4	1335	1997	2007	2017	2027
1986	Cattenom 1 P'4	1300	1997	2006	2016	2027
1986	Chinon B3 CP2	905	1999	2009	2019	2029
1986	Flamanville 2 P4	1330	1998	2008	2019	2029
1986	Paluel 4 P4	1330	1998	2008	2019	2029
1986	St-Alban 2 P4	1335	1998	2008	2018	2028
1987	Belleville 1 P'4	1310	1999	2010	2020	2030
1987	Cattenom 2 P'4	1300	1998	2008	2018	2028
1987	Chinon B4 CP2	905	2000	2010	2020	2030
1987	Nogent 1 P'4	1310	1998	2009	2019	2029
1988	Belleville 2 P'4	1310	1999	2009	2019	2029
1988	Nogent 2 P'4	1310	1999	2010	2020	2030
1990	Cattenom 3 P'4	1300	2001	2011	2021	2031
1990	Golfech 1 P'4	1310	2001	2012	2022	2032
1990	Penly 1 P'4	1330	2002	2011	2021	2031
1991	Cattenom 4 P'4	1300	2003	2013	2023	2033
1992	Penly 2 P'4	1330	2004	2014	2024	2034
1993	Golfech 2 P'4	1310	2004	2014	2025	2034
1996	Chooz B1 N4	1500	2010	2020	2030	2040
1997	Chooz B2 N4	1500	2009	2019	2029	2039
1997	Civaux 1 N4	1495	2011	2021	2031	2041
1999	Civaux 2 N4	1495	2012	2022	2032	2042

*Net continuous power

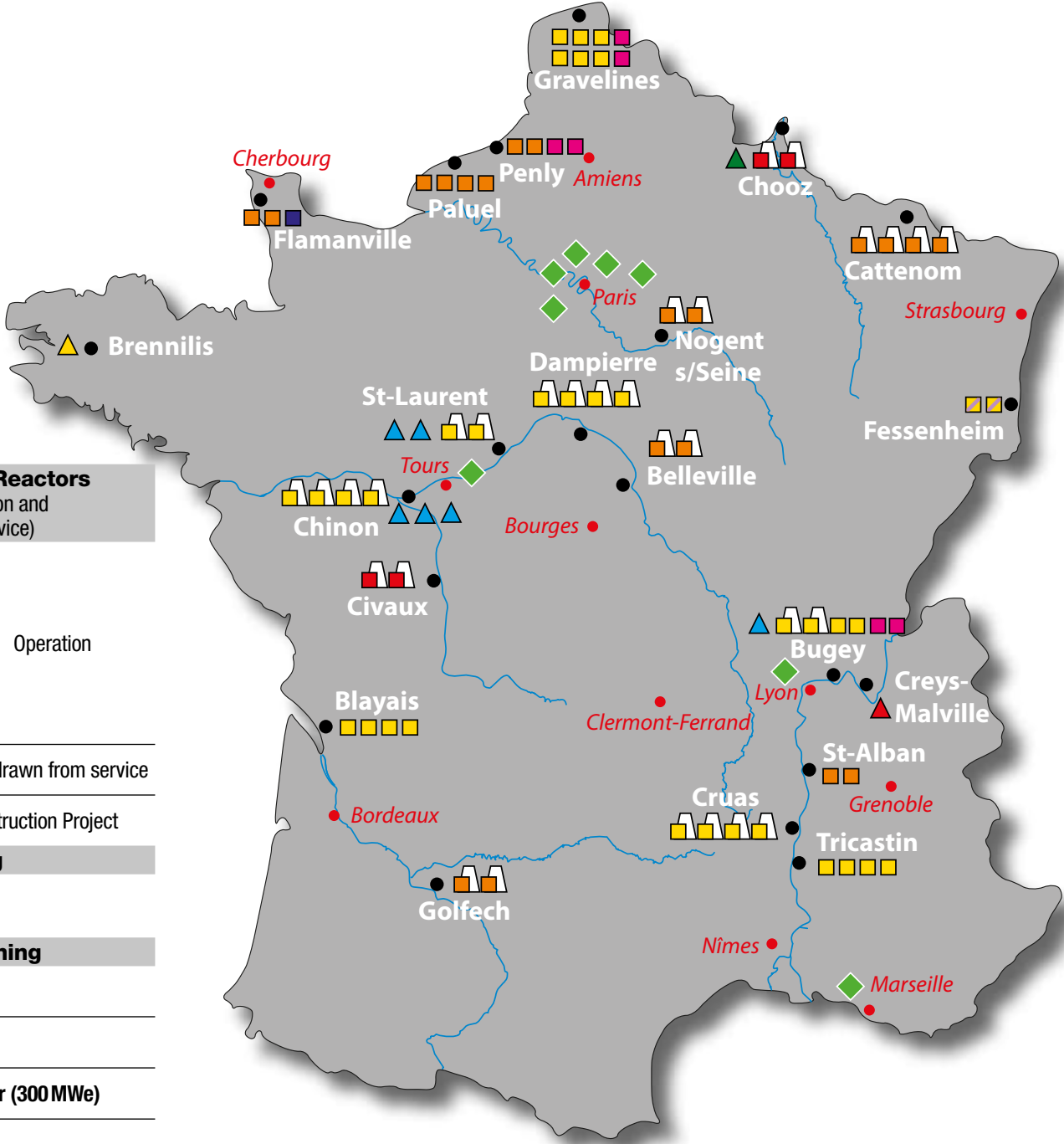
KEY DATES FOR THE EDF ENERGY NUCLEAR UNITS

Year in service	Nuclear unit	Reactor number	Power MWe	Planned date of withdrawal from service
1976	Hinkley Point B	R3	480	2022
1976	Hinkley Point B	R4	475	2022
1976	Hunterston B	R3	480	2021
1976	Hunterston B	R4	485	2022
1983	Dungeness B	R21	525	2021
1983	Dungeness B	R22	525	2021
1983	Heysham 1	R1	580	2027
1983	Heysham 1	R2	575	2027
1983	Hartlepool	R1	595	2027
1983	Hartlepool	R2	585	2027
1988	Heysham 2	R7	615	2030
1988	Heysham 2	R8	615	2030
1988	Torness	R1	590	2030
1988	Torness	R2	595	2030
1995	Sizewell B		1198	2035

EDF SA NUCLEAR SITES

-  Closed loop cooling
-  Open loop cooling

Pressurised Water Reactors (operation, construction and withdrawn from service)			
32	900 MWe	Operation	
20	1 300 MWe		
4	1 450 MWe		
1	1 600 MWe (EPR)		
2	900 MWe	Withdrawn from service	
6	1 670 MWe (EPR2)	Construction Project	
Engineering			
8	Engineering centre		
Decommissionning			
6	Gas-Cooled Reactor		
1	Heavy Water Reactor		
1	Pressurised Water Reactor (300 MWe)		
1	Fast Breeder Reactor		



EDF ENERGY NUCLEAR SITES



FRAMATOME SITES

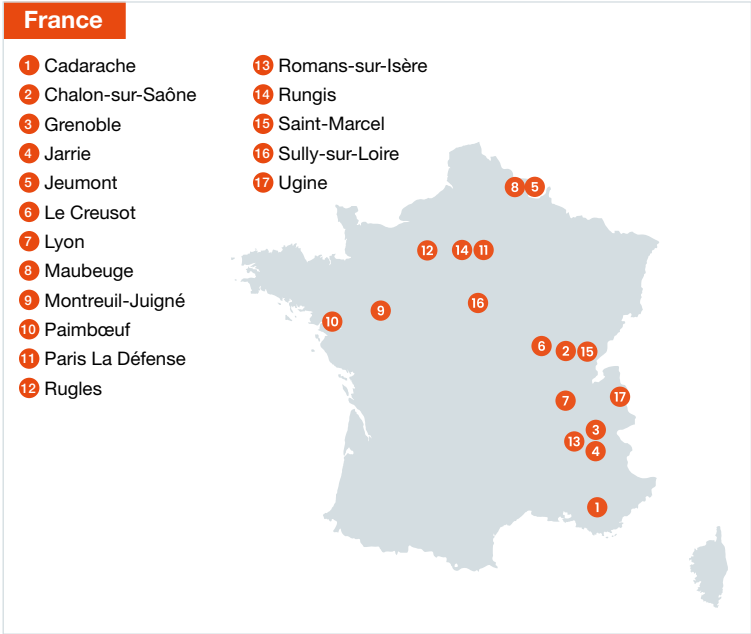


TABLE OF ABBREVIATIONS

A

AAR	Automatic reactor trip
AFI	Area for improvement
AGR	Advanced Gas-cooled Reactor
AIP	Activity important for protection (health, safety and environment)

ALARP	As Low As Reasonably Practicable
AIEA	Voir I = IAEA
ALARA	As Low As Reasonably Achievable
AMR	Manual reactor trip
AMT	EDF fleet maintenance agency
ANDRA	National Radioactive Waste Management Agency (F)
ARENH	Regulated access to incumbent nuclear electricity, established in Fr law 2010
ASN	Nuclear Safety Authority (F)
AT	Outage
ATEX	Explosive atmosphere

B

BWR	Boiling Water Reactor
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C

CCL	Local emergency response centre
CEA	Alternative Energies and Atomic Energy Commission (F)
CEFRI	Committee for the certification of companies in training and monitoring radiation workers (F)
CETIC	PWR Nuclear Steam Supply System Fieldwork Technical Validation Experimental Centre
CGN	China Guangdong Nuclear Power Company (China)
CIPR	International Commission on Radiological Protection (ICRP)
CLI	Local information centre
CIGEO	Project for underground storage of radioactive waste (F)
CNC	Civil Nuclear Constabulary (UK)
CNEPE	Electromechanical & plant engineering support department
CNPE	Nuclear Power Station
CNRS	National centre for scientific research (F)
COLIMO	A DPN campaign to modernise isolation and alignment practices and methods
COMSAD	Start-up nuclear safety committee (F)
COMSAT	Unit outage nuclear safety commission
COPAT	Unit outage operational control committee
CPO	Crew Performance Observation

CRT	Technical standards committee
CRESS	Significant nuclear safety event investigation report (F)
CSN	Council for Nuclear Safety
CSNE	DPN nuclear safety review meeting
CTO	Central Technical Organisation

D

DACI	Independent oversight directorate for EDVANCE
DART	Diagnostic and Repair Team (UK)
DBUE	Deployable Back-Up Equipment (UK)
DCC	Core-fuel directorate
DCN	Nuclear fuel division
DFISQ	Independent nuclear safety and quality oversight department (DIPNN)
DQI	Division for Industries Quality
DIPDE	Nuclear fleet engineering, decommissioning & environment division
DIPNN	Engineering & new-build projects directorate
DOE	Department Of Energy (US)
DP2D	Decommissioning & waste directorate
DPN	Nuclear generation division
DPNT	Nuclear & conventional fleet directorate
DRS	Nuclear safety standards directorate
DSPTN	Project support and digital transformation division at the DIPNN
DT	Technical division at the DIPNN
DTEAM	Conventional fleet multi-disciplinary expertise & industrial support division
DTEO	Transformation and operational efficiency directorate
DTG	General technical division
DTI	Engineering and technical directorate (Framatome)

E

EATF	Enhanced Accident-Tolerant Fuel
EDT	Dedicated field team
EDVANCE	Joint venture between EDF and Framatome (80% and 20% respectively)
EGE	Overall nuclear safety assessment
EIP	Equipment protected for nuclear reasons
EIPS	Equipment protected for nuclear safety reasons
EMAT	Shared teams providing support during unit outages
EIR	Rapid Maintenance Response Team (F)
EIR	Interesting radiation protection event (F)
EPR	European Pressurised Reactor
EPRI	Electric Power Research Institute (US)

ESPN	Nuclear pressure equipment
ESR	Significant radiation protection event (F)
ESS	Significant nuclear safety event (F)
EVEREST	EDF project to allow workers to enter controlled areas wearing ordinary work clothes

F

FARN	Nuclear rapid reaction force
FIN	Fix it Now Team (UK)
FIS	Independent nuclear safety oversight (F)
FME	Foreign Material Exclusion
FSAT	Fire Safety Action Team (UK)

G

GDA	Generic Design Assessment (UK)
GECC	Core design and engineering group (F)
GIEC	Intergovernmental panel on climate change (IPCC)
GIFEN	Nuclear Energy Industry Group (F)
GK	Fleet upgrade programme (F)
GPEC	Advanced planning of jobs and skills
GPSN	Nuclear safety performance group (UNIE)

H

HCTISN	High committee for transparency and information on nuclear matters
HOF	Human and organisational factors
HPC	Hinkley Point C (UK)
HPT	Human Performance Tools

I

IAEA	International Atomic Energy Agency
ICPE	Environmentally regulated facility
ICRP	International Commission on Radiological Protection
IFOPSE	Fire Safety & Prevention Training Institute (F)
IN	Nuclear inspectorate (DPN)
INA	Independent Nuclear Assurance (EDF Energy)
INB	Licensed nuclear facility (F)
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operators (US)
INSAG	International Safety Advisory Group (IAEA)
IPCC	Intergovernmental panel on climate change (UN)
IRAS	Plant engineer assigned to relations with the ASN (NPPs)
IRSN	Institute for radiation protection and nuclear safety (F)

J	
JDO	Joint Design Office (UK)
L	
LLS	Turbo-alternator last-resort power supply
LNHE	Hydraulic and Environmental National Laboratory
LOCA	Loss-Of-Coolant Accident
LTIR	Lost-Time Injury Rate
M	
MAAP	DPNT performance assessment and support team
MARN	Nuclear hazard management support team
MDL	Second-line manager
MEEI	Campaign for maintaining exemplary housekeeping (DPN initiative)
MEH	Mechanical, Electrical and HVAC (UK)
MLC	Onsite emergency response means
MME	Operations and maintenance methods
MOX	Nuclear fuel comprising 8.5% plutonium and 91.5% enriched uranium (F)
MPL	First-line manager/front line manager
MQME	Campaign to raise the standards in maintenance and operation (DPN)
MVM	Maintenance optimisation programme (F)
N	
NCC	Operations core skills handbook
N3C	Tagging and plant configuration errors
NCME	In-service maintenance professions common core
NC STE	Non-compliance with technical specifications
NDA	Nuclear Decommissioning Authority (UK)
NDT	Non-destructive testing
NEA	Nuclear Energy Agency (OECD)
NEI	Nuclear Energy Institute (US)
NNB	Nuclear New Build (EDF Energy)
NNSA	National Nuclear Safety Administration (China)
NPP	Nuclear Power Plant
NQME	Non-quality in maintenance and operations
NRC	Nuclear Regulatory Commission (US)
NSG	Nuclear safety group (UK)
O	
OIU	Internal inspection organisation
ONC	National emergency response organisation (F)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating experience
OSART	Operational Safety Review Team (IAEA)

OST	Task observation focused on skills and competences (F)
P	
PBMP	Basic preventive maintenance programme
PCCF	Creusot forge compliance project
PCC-EO	DPN skill advisory centre for organisational effectiveness (F)
PCI	Pellet-cladding interactions
PDC	Nuclear engineering key skills development plan
PFI	Human Performance Tools (HPT)
PGAC	Worksite general assistance services
PIRP	DPN industrial policy and contract partner relations team (F)
PLM	Plant Lifecycle Management
PPAS	Multi-year nuclear safety improvement plan (Framatome)
PPE	Personal Protective Equipment
PPI	Off-site emergency response plan (F)
PSPG	Police site protection unit (F)
PUI	Onsite emergency plan (F)
PWR	Pressurised Water Reactor
R	
R&D	Research & Development directorate
RASA	Rules and Specifications for Hazards
REP	Pressurised Water Reactor PWR
REX	Operating Experience (OPEX)
RGE	General operating rules (F)
RGV	Steam generator replacement
RIS	Emergency water injection system for reactor cooling
RTE	Power grid company (F)
S	
SAT	Systematic Approach to Training
SDIN	Nuclear technical information system
SDIS	Local fire and rescue services (F)
SIR	Authorised internal inspection department
SMART	Digitalisation programme at the DIPDE
SMI	Integrated Management System
SMR	Small Modular Reactor
SODT	Safety Oversight Delivery Team
SOER	Significant Operating Experience Report issued by WANO
SOH	Socio-organizational and human approach
SP	Standardised plant teams
SPR	Risk management department
SQEP	Suitably Qualified and Experienced Person

STE	Technical specifications
SWITCH	Digitalisation programme at the DIPNN
SYGMA	Computerised maintenance management system
T	
TCO	Technical Client Organisation (UK)
TEM	Online Work Management
Tfg	Occupational accident frequency factor (F)
TNPJVC	Joint venture between the Chinese company CGNPC (51%), Guangdong Yuedean Group Co. (19%) and EDF (30%)
TRIR	Total Recordable Injury Rate
TSM	Technical Support Mission by peers organised by WANO
TSN	Nuclear safety & transparency act (F)
TSSM	Technical Safety and Support Manager (UK)
TVO	Teollisuuden Voima Oyj (Finlande)
U	
UFPI	Operations & engineering training department (DTEAM)
UGM	EDF Group Management University
ULM	Maintenance & Logistics Unit (F)
UNGG	Gas-cooled graphite-moderated reactor (F)
UNIE	Operations engineering unit (DPN)
UTO	Central technical support department (DPN)
V	
VC	Initial inspection outage
VD	Ten-yearly inspection outage
VP	Partial inspection outage
W	
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association



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The olympic flame

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