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Webinar

The French EPR: the future of nuclear expansion or rather a failed technology?

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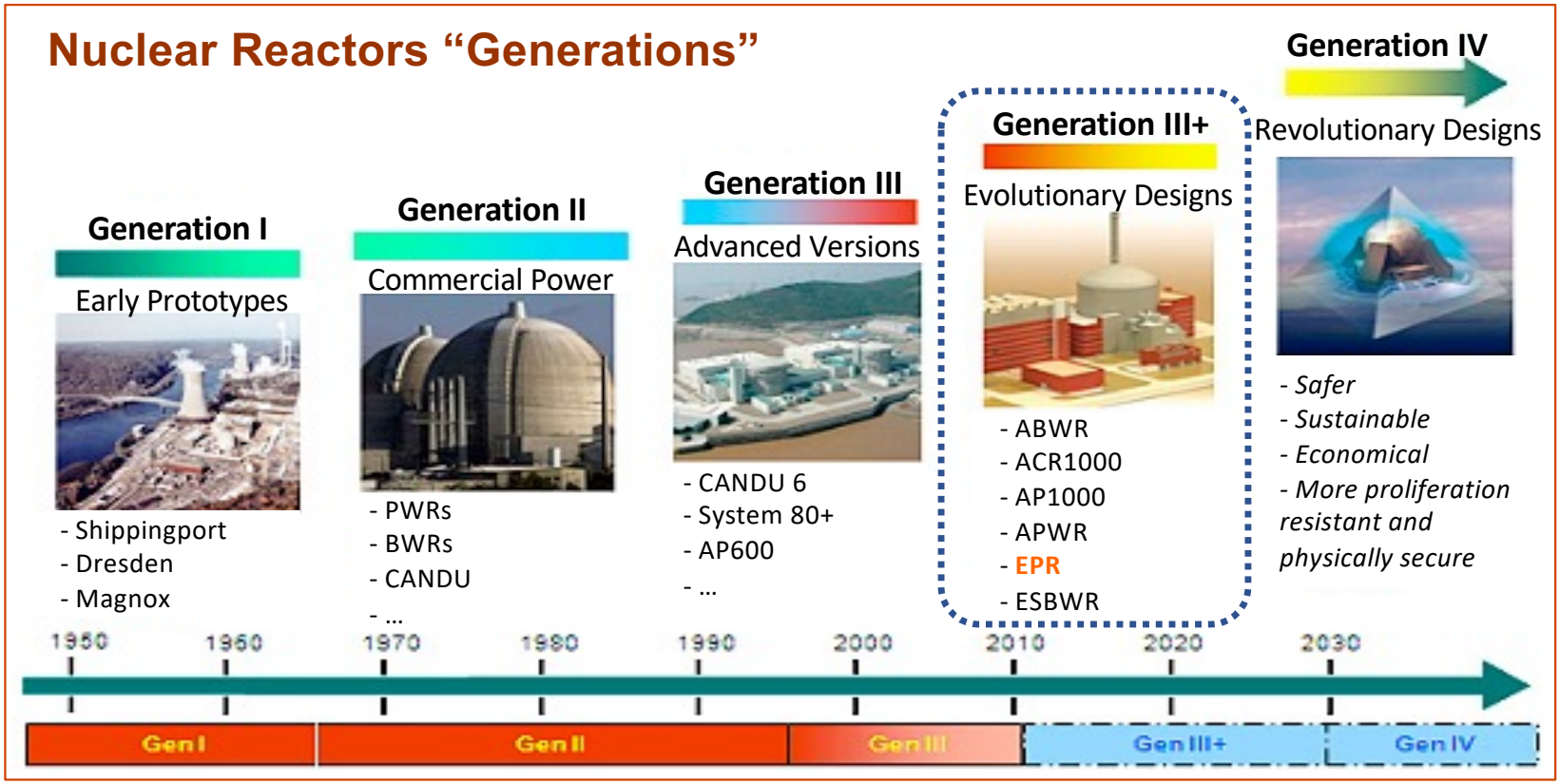
Joint Project
Nuclear Risk & Public Control
19 September 2022

Part 1

Design deficiences of the Flamanville-3 EPR

EPR as an “evolutionary design”

- **Generation III / IV** is a concept introduced in the 1990s to promote new reactors
- **EPR is part of Generation III+ so-called “evolutionary designs”**

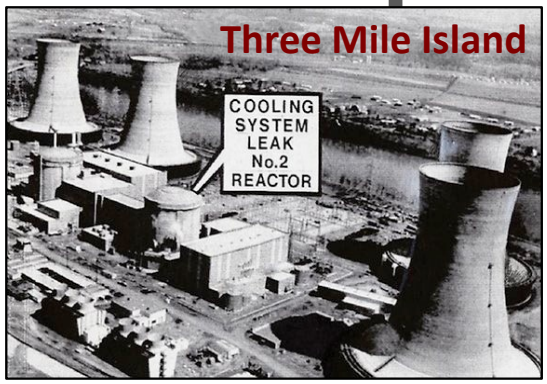


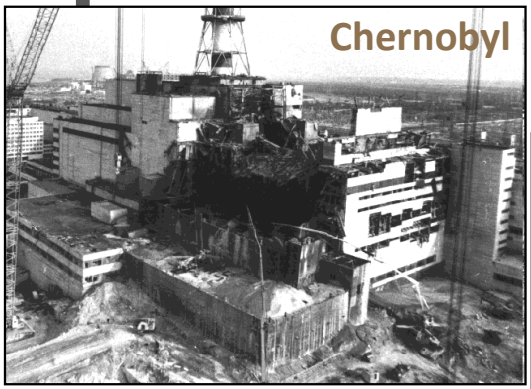
EPR design history

Development of EPR

1970 1980 1990 2000 2010 2020

1979 1986 1992 2001 2011





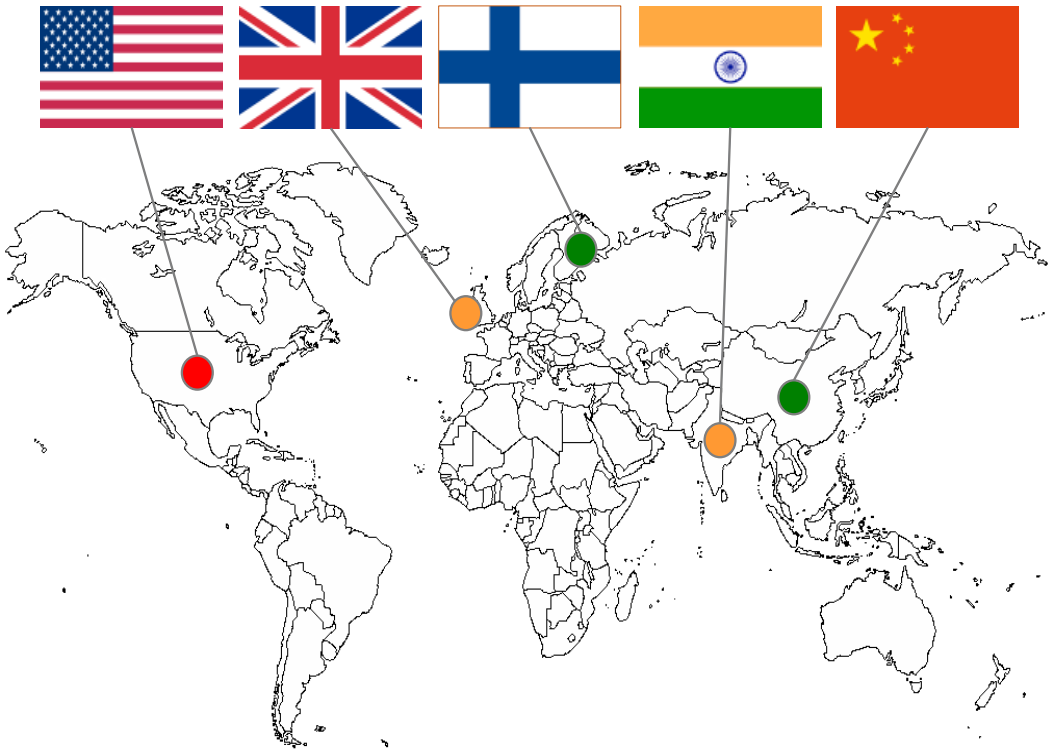
EPR Flamanville project

Brief EPR project history:

- French/German development of a new up to 1,800 MWe design, project started in 1992s
- 1996-97, global design complete
- 2003, French decision to order a French EPR to prepare for future replacement (anticipate)
- 2005, final decision to build an EPR in Flamanville
- 2007, construction license is granted, EDF plans to get it built by 2012

EPR programme

The international EPR programme

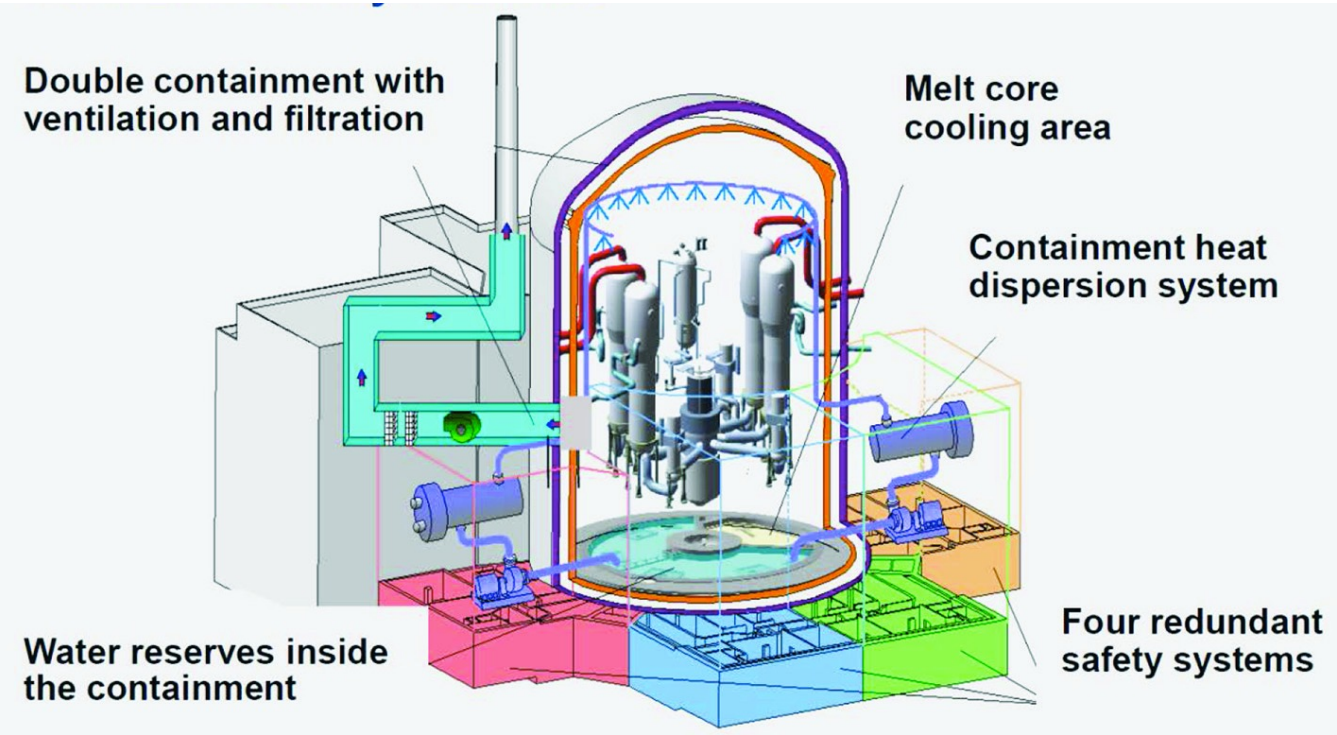


- **Finland:**
  one unit started (Olkiluoto-3)
- **China:**
  two units operating (Taishan-1 and 2)
- **USA:**
  projects developed now abandoned
- **United-Kingdom:**
  two units under construction (Hinkley Point-C), pending project (Sizewell)
- **India:**
  project to build up to six units in Jaitapur, no financing perspectives

International development remains very far from the expectations of the industry

Increased complexity

Main safety features introduced in EPR



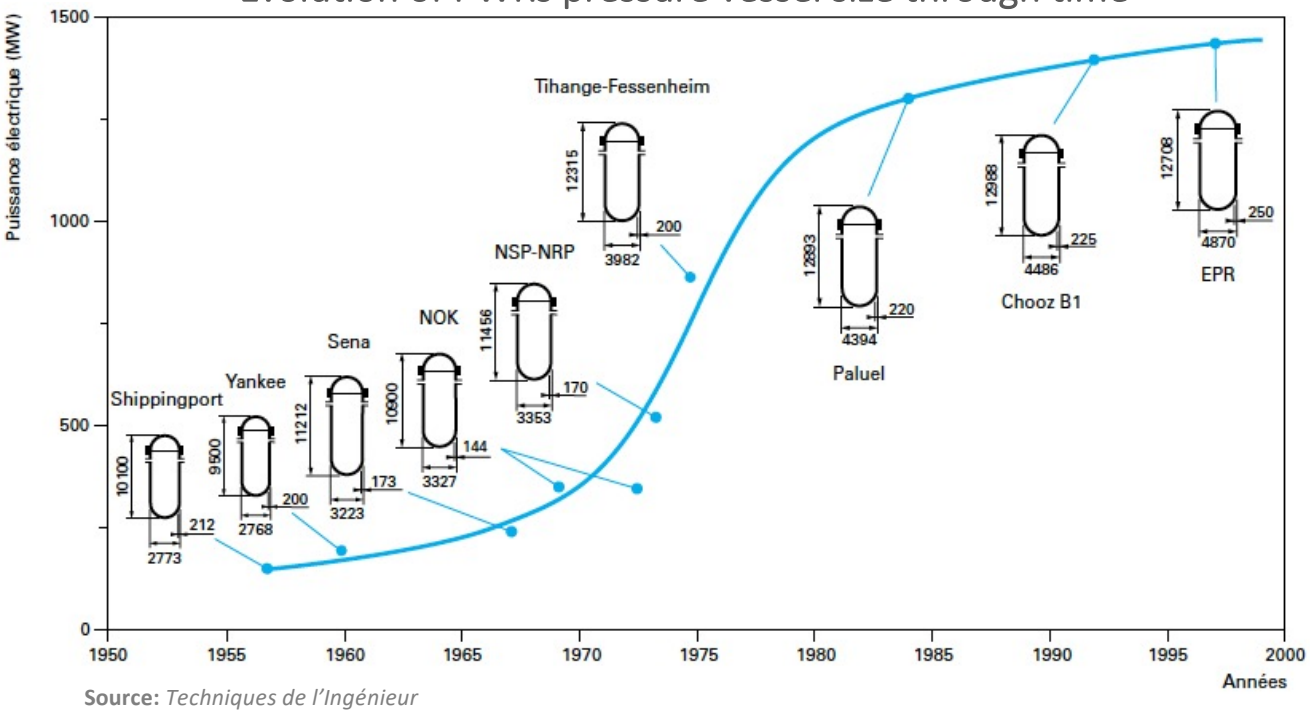
Source: WNA, 2015

- The evolutionary descendant of the Framatome N4 and Siemens "Konvoi" reactors
- Combines in a multiple layer approach their improvements
- Reinforced containment, reinforced and more redundant safety features
- New features (“core-catcher”)
- Objective: reduce maximum core damage frequency to 10^{-7}/y and **eliminate the need for evacuation of populations**

New safety features introduced in the design of EPR mark a real improvement
but remains pre-Fukushima based, French ASN said in 2011 this is still possible with EPR

Increased potential for danger

Evolution of PWRs pressure vessel size through time



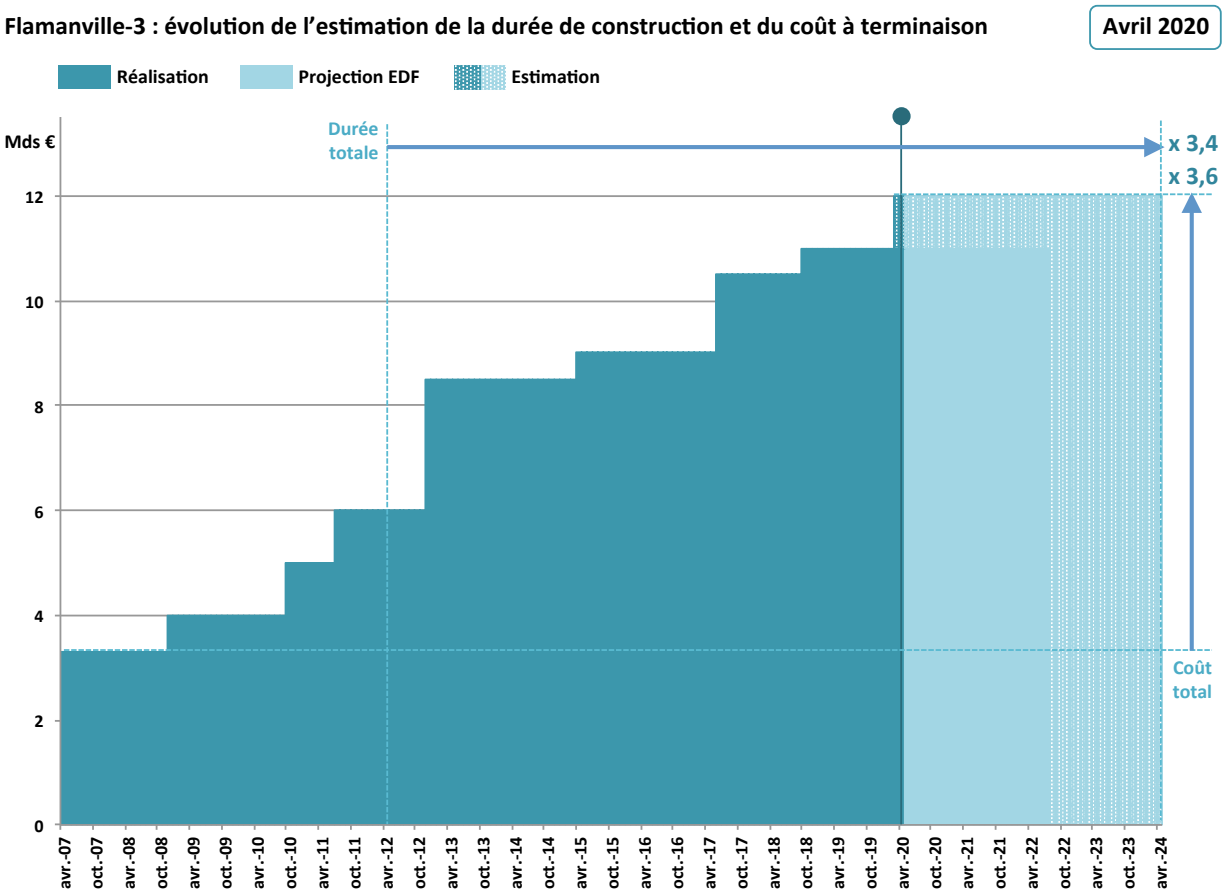
Source: *Techniques de l'Ingénieur*

- Design output 1,600 MWe, up to 1,800 MWe: the most powerful reactor ever built
- Aims for increased fuel burn-up (up to 70 GW.d/t)
- Unprecedented radioactivity inventory both in the reactor core and in the spent fuel pool
- Unprecedented thermal output in the core and the pool

The increased size of heavy components means they are bound to face heavier mechanical/thermal loads in operation

While the safety features are reinforced, the **potential for danger is increased** too

Soaring delays and costs

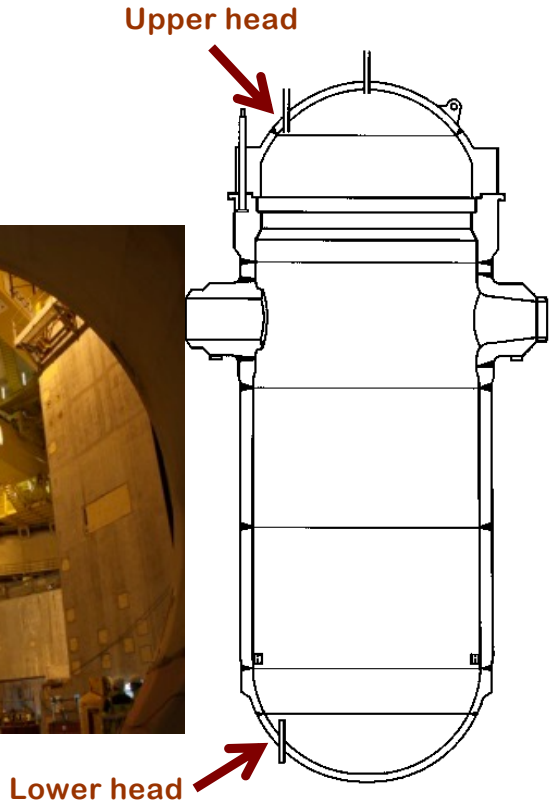


Construction of the EPR – Flamanville-3

- Initial plan to start it in 2012 at a cost of € 3,3 billion
- Latest official estimate: industrial service in 2023 for a cost of € 12 billion
- Cour des Comptes estimates, including financial cost: € 19 billion

Specific issues – Focus 1

Pressure vessel



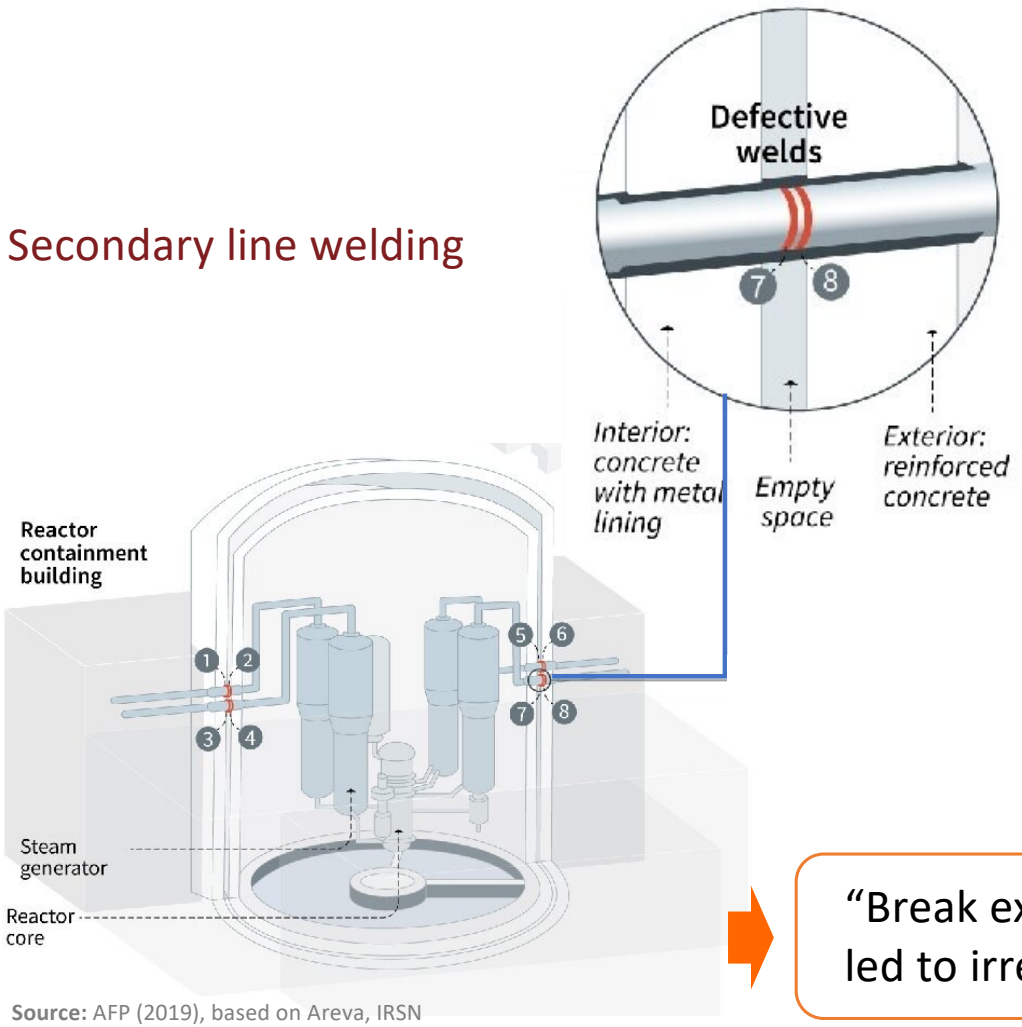
- **7 April 2015**: an “anomaly” with the head and bottom of the reactor pressure vessel
- Head and bottom forged in 2006 at Creusot-Forge though its limited ingot size capacity
- IRSN called this choice a “technical regression”
- Risks of anomaly (carbon concentrations) were well known
- January 2014, reactor vessel is put in its pit and welding work (primary circuit) starts
- October 2014, long-delayed qualification tests reveal the anomaly
- **11 October 2017**: ASN grants approval for the vessel though “margins are lost by half” but requests replacement of upper head by 2024

First level of defense in depth (conception and fabrication) is irreversibly degraded

Proposed reinforcements of second level (operation) but there’s no third level

Specific issues – Focus 2

Secondary line welding



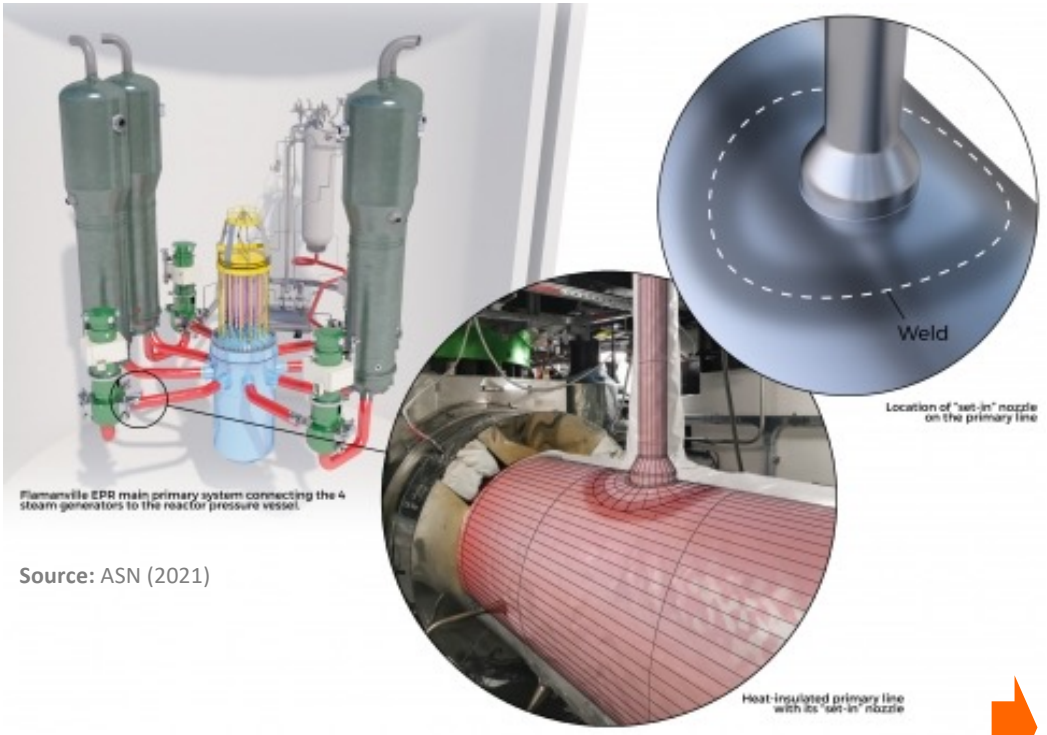
Source: AFP (2019), based on Areva, IRSN

- Quality issues with welds of the secondary loops detected in 2013, notified to EDF mid-2015, declared to ASN in 2017, made public in **February and April 2018**
- The secondary loops had been placed under an extended application of the **"break exclusion"** principle: quality of design and manufacturing must absolutely guarantee no breach is possible
- No mitigation planned in case of a breach
- All manufacturing, welding, on-site building work had been done before real control
- More than 100 welds concerned, of which 8 in the space between reactors walls
- 19 mars 2021: ASN agrees to the repairs of these 8 welds using dedicated robots

"Break exclusion" principle and mismanagement led to irrevocably compromise the first line of defense-in-depth

Specific issues – Focus 3

Primary line “set-ins”



Flamanville EPR main primary system connecting the 4 steam generators to the reactor pressure vessel.

Source: ASN (2021)

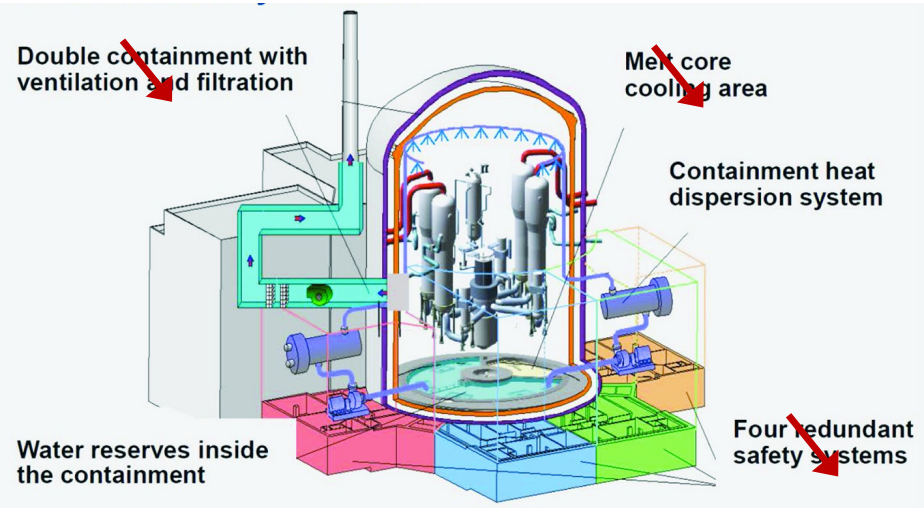
- **March 2021**: “anomaly” with set-in of auxiliary piping on the primary loops
- Diameter of welds has been significantly extended in the design phase in 2006
- This compromised the safety studies (increased the reference size of breach to be considered)
- The issue remained unnoticed by EDF until 2013, after manufacturing and on-site building complete
- Instead of declaring to ASN, EDF decided to apply a posteriori the “break exclusion” … and modified the corresponding requirements to fit
- This was discovered by chance in 2020-2021
- ASN agreed to repair through a massive collar around the welding

“Break exclusion” principle and mismanagement damage the confidence in safety

Part 2

Design changes of the EPR 2
and capacity of the French nuclear industry

Change of design



EPR NM (new model) proposed in 2018

- Increase in core power (1800 MWe)
- Reduction from 4 trains to 3 for backup systems (safety injection, emergency power supply to steam generators, etc.);
- Changeover to a simple containment with a liner;
- Simplified design of the core-catcher (reduced spreading surface);
- Removal of the two-room concept (no access to reactor building in operation);
- Removal of the nuclear auxiliary building

EPR 2 proposed in 2021

- Return to 1650 MW
- Extension of “break exclusion” principle

Basic design still under review

Planned EPR2 programme

Source: *Contexte* (2021), leaked Government note

Plans to build new reactors EPR2

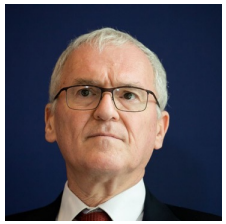
- Simplified design, recession on key safety features meant to reduce building costs
- Still in early design phase, generic license planned ~ 2025
- First official cost estimate: at least **€ 46 billion** for 6 reactors and official leadtime: first reactor in operation by 2035
- Leaked Government estimate, October 2021:
  - increase of planned cost by 13% between early 2020 and mi-2021 with no clear explanation
  - reasonably no first service before 2037 at the earliest
  - total cost raised to € 52 to 57 billion, up to € 64 billion in an industrially “degraded” scenario
  - the “concept” will be completely confirmed by 2025-2027

Certains choix de conception structurants restent à confirmer auprès des autorités de sûreté et de sécurité nucléaires, pour lesquels une décision défavorable entrainerait soit la remise en cause du projet soit d'importants surcoûts et décalages de calendriers. Le concept EPR2 pourra ainsi être complètement confirmé à l'horizon 2025/2027 et sa déclinaison opérationnelle à un niveau de maturité suffisant est attendue à l'horizon 2027/2029.

La protection contre les chutes d'avions et d'aéronefs sur le bâtiment réacteur est assurée pour l'EPR par l'enceinte externe de la double coque ; pour l'EPR2, la simple enceinte, plus épaisse, a vocation à apporter la double protection contre les agressions externes et contre les pressions internes. Ce sujet relevant de la sûreté et de la sécurité', l'autorité de sûreté nucléaire et le haut fonctionnaire de défense et sécurité devront se positionner sur la capacité de l'enceinte à jouer ce rôle. A ce stade, les travaux de modélisation réalisés par EDF n'ont pas apporté les éléments de confort suffisants. Ce sujet

Industrial capacity…

Jean-Bernard Lévy
CEO of EDF, 2014- …

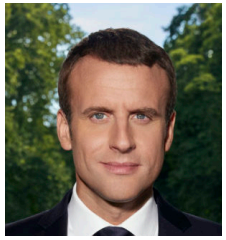

(François Nascimbeni/AFP)

"EDF is like a cyclist who has to pedal not to fall"

Hearing at the National Assembly, 7 June 2018

› Ambitious objectives are needed to sustain capacities…

Emmanuel Macron
President of the Republic, 2017- …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"France's energy and ecological future depends on nuclear power"

Speech at Creusot-Forge, 8 December 2020

› Life extension of reactors to 60 years
Newbuild of 6 to 14 EPR2 reactors

Bernard Doroszczuk
President of ASN, 2018- …

"If the nuclear choices are confirmed, the industry and the public authorities will have to put in place a real Marshall Plan to make this prospect industrially sustainable"

Hearing by the Parliamentary Office for Scientific and Technical Choices, 17 May 2022


(François Nascimbeni/AFP)

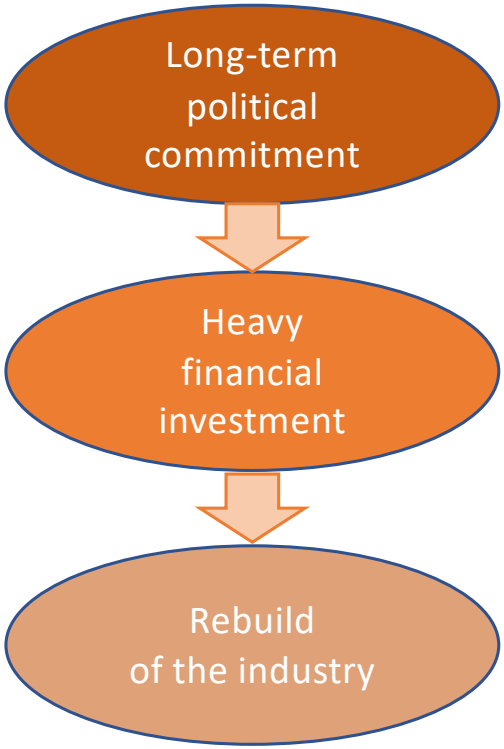
A "Marshall plan" is needed to revive the nuclear industry

Hearing at the National Assembly, 14 September 2022

› Capacities are needed to sustain objectives…

Unlikely rebuild of capacities

A “Marshall plan”… whose conditions are themselves difficult to meet



Impossible to guarantee over the 6 five-year political mandates required to complete the programme

Very difficult to gather in a context of increasing loss of competitiveness and attractiveness of this option

Highly challenging to reconstruct a very large heavy industry fabric to support a programme isolated from the rest of the economy

Any plan for export will even further stretch the existing industrial capacities, reinforce the challenge and increase the risk of failure

Thank you for your attention!

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