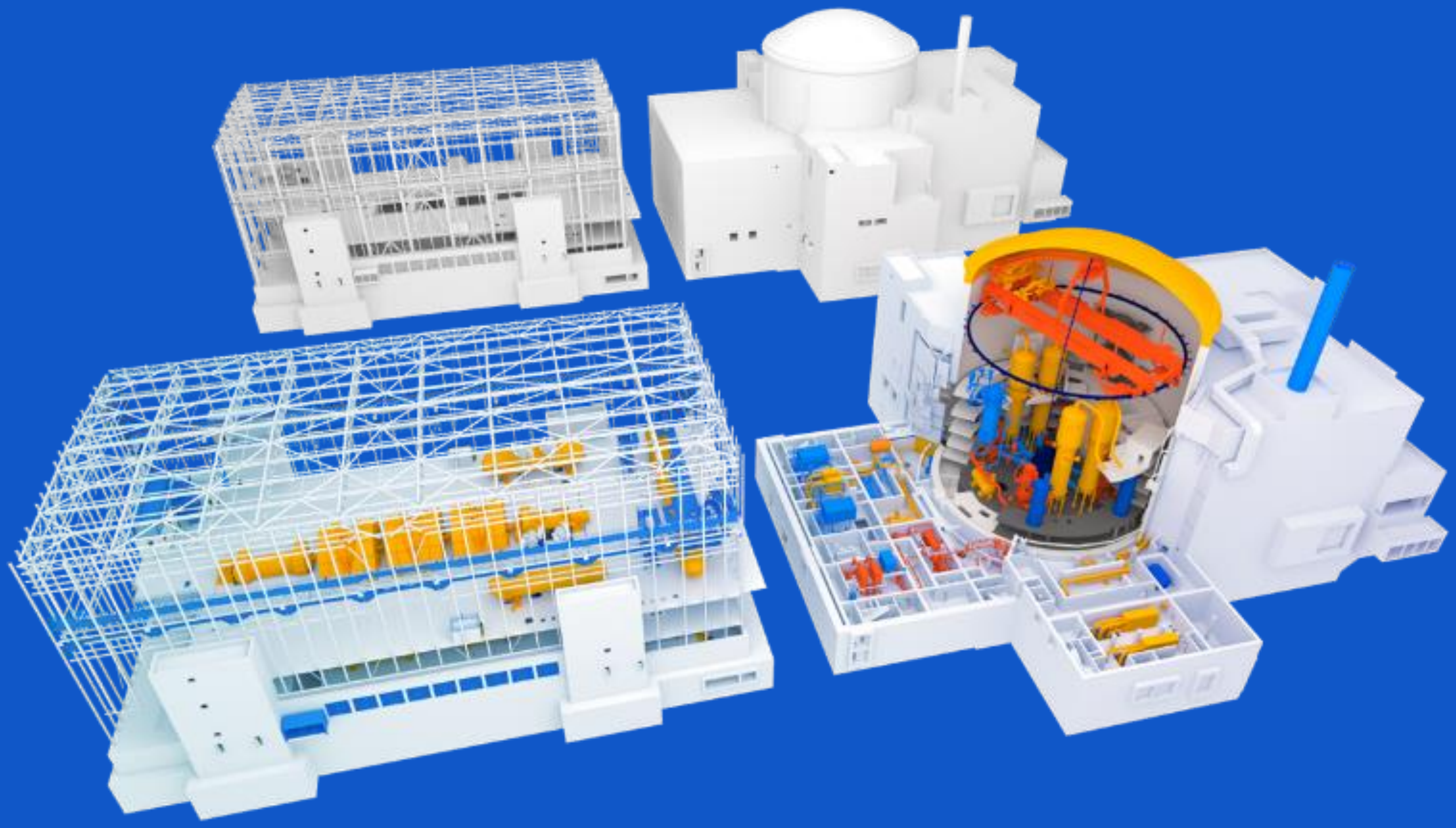
Radiation Protection optimization at design stage :
application to EPR2

Matthieu Longeot, EDVANCE/EDF
Sébastien Poirrier, EDVANCE/Framatome

ISOE International Symposium
Tours, 21-23 June-22



Summary

1) Introduction:

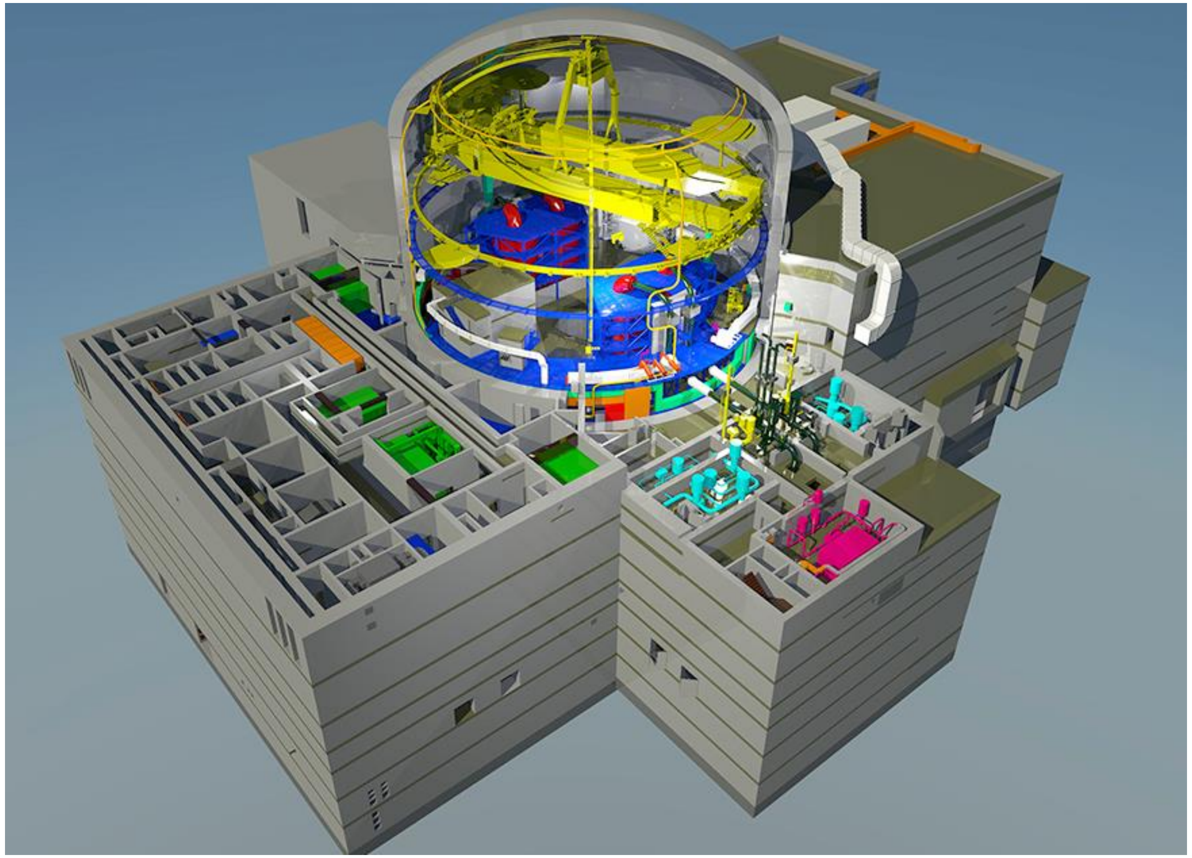
- Overall EPR2 design
- EDF Generation RP Referential

2) General RP requirements and ALARA approach for EPR2

3) EPR2 "dose rate" objectives

4) EPR2 collective dose optimization

5) Cleanliness/waste considerations at design



edvance GROUPE EDF

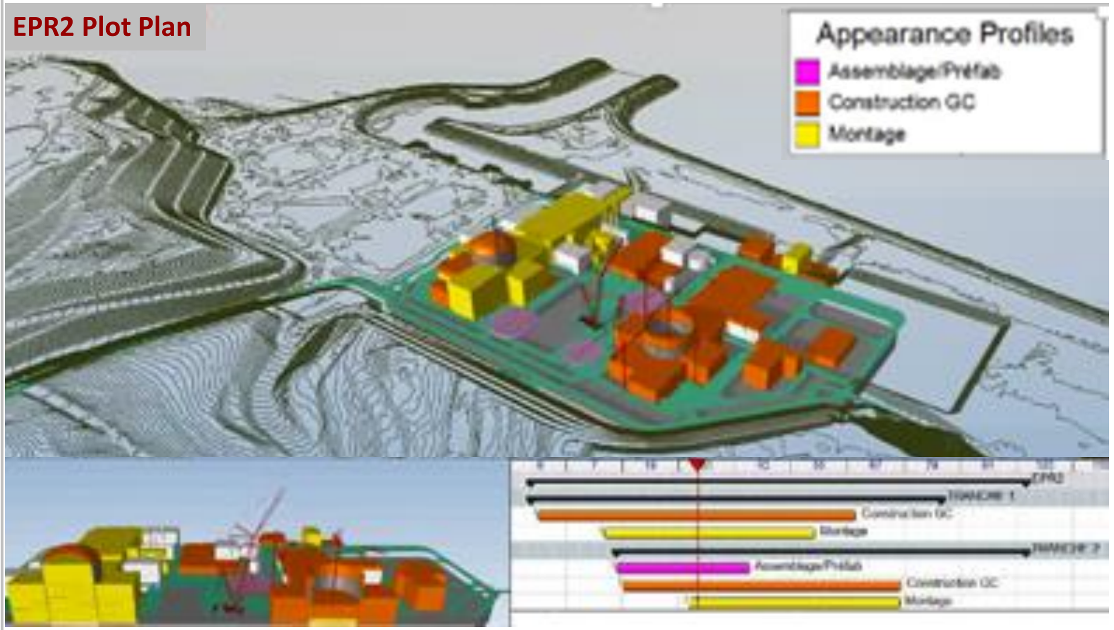
1.1 EPR2 design: General presentation

EPR2 design model of EDF Group -> "EPR based" and with:

❖ **Optimization of EPR2 constructability, cost and delay:**

- Integration of: - **operating experience** from previous EPR construction and best operating French NPPs

- Simplified design: for ex. **equipment standardization**



- Design the NPP via 3D and 4D Mockup -> **"Numerical Twin"**

- Digitalized process (System Engineering) and data available to an **"Extended Enterprise"**

- **But keeping the same high safety** and environmental performances as EPR (among the highest in the world)

❖ **EPR2 Project goal:** to file a submission to build 3 **EPR2 twin units in France**

❖ **EDVANCE (an EDF and Framatome subsidiary) is in charge of the EPCC *(*)* of EPR2 NI**

edvance GROUPE EDF

(*) EPCC: Engineering, Procurement, Construction and Commissioning

1.1 "EDF Generation" RP Referential" -> focus on "design part" and dose optimization

Constraints and OPEX (French fleet) are taken into account by EDVANCE in the design

In particular the following topics of "RP Referential":

- **Optimization of source term**
- **Radiological cleanliness** / EVEREST
- **Waste management**
- **RP design Referential**

provides « RP design requirements »

- **Radioactive sources et "radio. shootings"**
- **Metrology**
- **Management of zoning (installations)**
- **Management of internal transport**

"EDF Group" RP referential:

"Cascaded" into **EPR2** Design Procedures like:

- Dose rate room classification and radiological zoning
- Cleanliness/Waste Zoning
- Definition of aerosol/iodine risk rooms

2. General RP requirements and ALARA approach

- RP requirements are claimed for radiation protection for:

- *Layout, Civil Works*
- *HVAC (Heating Ventilation and Air Conditioning)*
- *Equipment and systems.*

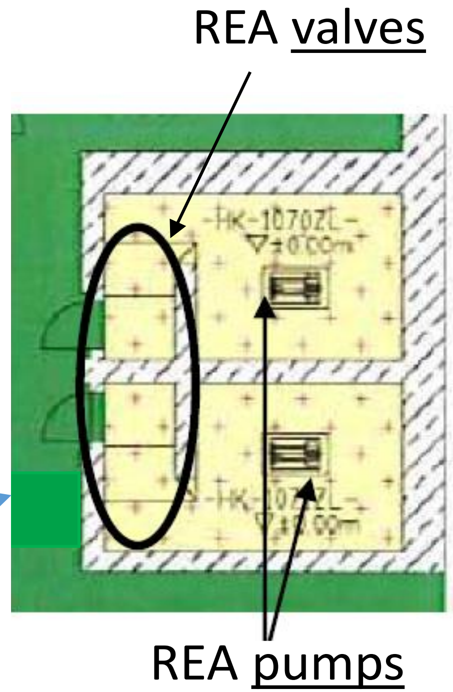
- Examples of general layout requirements

> Good accessibility to equipment requiring regular maintenance,

> Shielding mazes to access to active equipment and control valves -> located near the room entrance

> Sufficient space is foreseen for:

- a low dose area to prepare and monitor the activities;
- Maintenance of the equipment in the installation



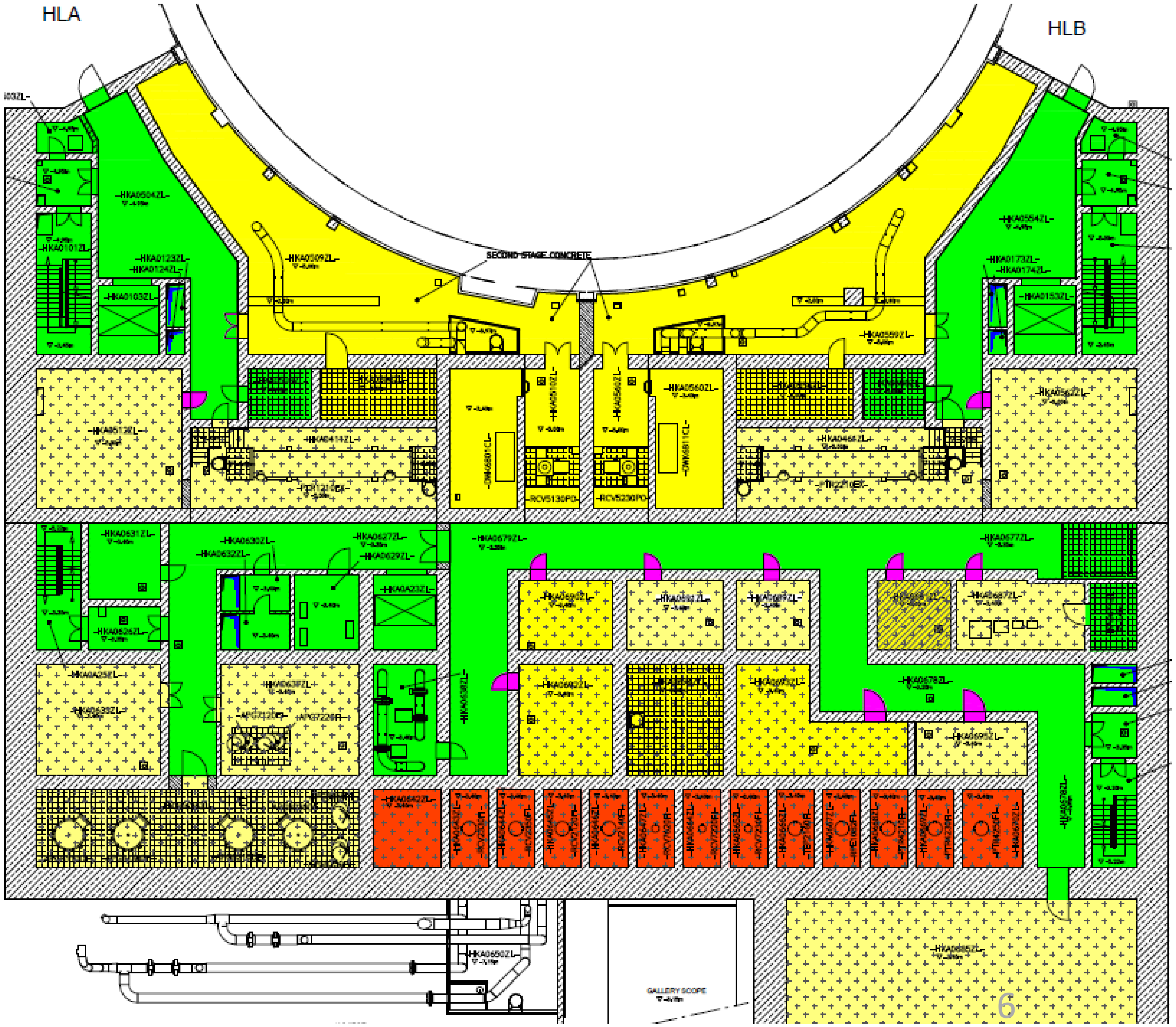
- Use of the good performances of existing plants and of operational feedback

- Dose optimization for the most exposed activities and workers.

Examples of Layout-CW design requirement

Radiological Zoning – *BD EPR2 Fuel Building level -3.4m*

RADIATION PROTECTION ROOM CLASSIFICATION												
SUBZONE		GREEN ZONE		CLEAR YELLOW ZONE		DARK YELLOW ZONE		ORANGE ZONE			RED ZONE	
DOSE RATE		10 µSv/h	25 µSv/h	0.1 mSv/h	0.2 mSv/h	1 mSv/h	2 mSv/h	10 mSv/h	30 mSv/h	0.1 Sv/h	0.3 Sv/h	
Rooms with no iodine risk	No aerosol risk or non-fixed contamination	A	2.5A	B1	2B1	C1	2C1	D1	3D1	E1	3E1	F1
	Aerosol risk	--		B2	2B2	C2	2C2	D2	3D2	E2	3E2	F2
Iodine risk		--		B3	2B3	C3	2C3	D3	3D3	E3	3E3	F3
Access		Regulated work area		Regulated stay area				Limited stay area				



3. EPR2 dose and dose rates objectives (1/2)

- Presented in EPR2 DOS (Safety Option File) and the “EPR2 PSAR”:
  - Collective dose of **0.35 Man.Sv/yr/unit averaged over 10 years** (comparable to best French units and int’l);

- Other **EPR2 RP objectives in terms of dose rate** at design stage:
  - **7.5 µSv/h** (blue): hot laboratory;
  - **10 µSv/h**: frequent passageways (corridors, staircases) and sampling laboratories;
  - **25 µSv/h** (green): Access to working areas, safety exits, control valves rooms, edge of spent fuel pool; edge of the refueling cavity (in reactor building)
  - **2 mSv/h** (yellow): Some circulation areas of Reactor building plant at power (to allow access for exceptional situations, e.g. for safety) -> as on French Fleet.

4. EPR2 collective dose optimisation: Approach and application (2/2)

Reference collective dose — **0.44 Man.Sv/yr/unit**

<u>Design evolutions of EPR2 concerning Radiation Protection</u>

- Source Term
- Dose rates
- Exposure time

EPR2 initial collective dose assessment — **0.37 Man.Sv/yr/unit**

<u>Optimization</u>

Priority to activities with <u>high dose level</u>
(contributing to more than 50 % of collective dose) :

- **Thermal insulation *(installation/removal)***
- **Opening and closing of reactor vessel**
- **Steam generator controls**
- **Waste sorting and conditioning**
- **Logistics, *incl. scaffolding***
- **Primary Valves**
- **Conventional safety and RP**
- **boilermaking intervention**

EPR2 optimized collective dose

<u>Synthesis</u>:
The RP optimization being taken into account early at design stage
-> confidence that the EPR2 will meet the objective of <u>0.35 Man.Sv/yr/unit</u>

4. EPR2 dose optimization: Reference collective dose

- The Reference collective dose is based on:
  - The Operational Feedback on the period **2012-2017**, => available on **ISOE**
  - Dose statistics of the best French nuclear plants

- Best recent plants in terms of dosimetry: P'4 (newest 1300 MWe) and N4 (1450 MWe):
  - 18-month cycle,
  - Averaged over 10 years with the following outage cycle considered: NRO-ROO-NRO-ROO-NRO-ISIO
    - 3 Normal Refueling Outages (NRO)
    - 2 Refueling Only Outages (ROO)
    - 1 "10-year outage" (ISIO)

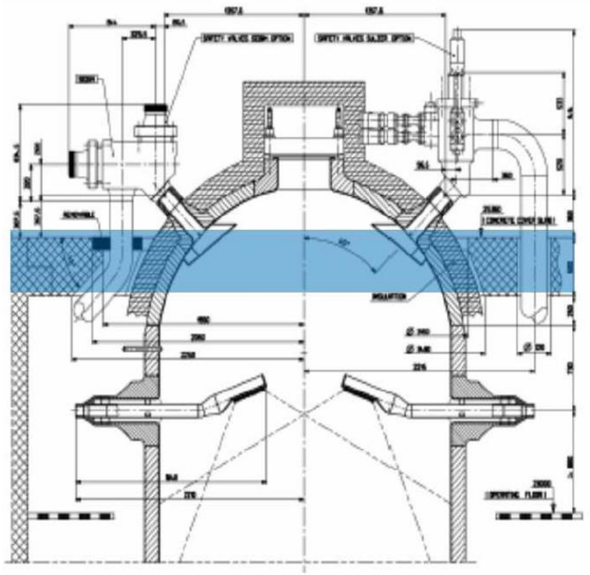
Reference collective dose: 0.44 Man.Sv/yr/unit

4. ALARA approach: EPR2 Initial Collective Dose: EPR2 Design Evolutions (1/2)

- **Source term**
  - Selection of materials to limit the presence of corrosion products that can be activated under neutron flux -> E.g. limitation of Stellite™ in valves and RPV internals to minimize Cobalt levels
  - Optimization of the main primary chemistry
    - ➔ global reduction of 15% in terms of dose rate

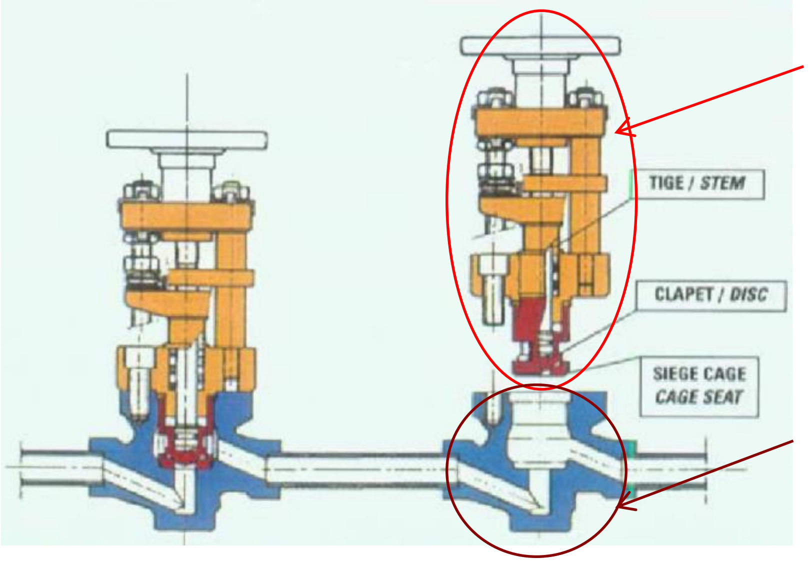
- **Dose rates reduction**
  - Building layout implementing installation rules to lower dose rates (separation of systems carrying radioactive materials)
  - Reduction of hot spot traps (ACPs)
  - Consideration of fixed shielding around equipment contributing the most to the radiological ambience in a room
  - Pressurizer spray lines separated from pressurizer relief valves by a concrete shielding slab
  - Electropolishing of SG water boxes
  - Improvement of valves tightness (e.g. double leaktightness barrier) on RCS, CVCS and RHRS systems

Pressurizer spray and discharge systems separated by a concrete floor at Pressurizer dome level to reduce the average dose rate in the safety valves area coming from the spray pipes



4. ALARA approach: EPR2 Initial Collective Dose: EPR2 Design Evolutions (2/2)

- **Exposure time limitation**
  - Building layout implementing installation rules to ease circulation and ease activities (room arrangement)
  - Fixed platforms (steel grating) around SG (manholes, eyeholes, handholes)
  - Optimization of SG maintenance/inspection program:
    -> E.g. no SG flushing or activities on primary/secondary sides in Refueling Only Outages
  - Optimization of SG channel head and use of fast mounting nozzle dams
  - Design considerations to limit the volume of activities on the RPV cover head in outage (e.g. absence of intervention opening/closing CRDM ventilation hatches)
  - Fast mounting thermal insulation
  - Use of valves with modular maintenance



-> 0.37 Man.Sv/yr/unit

4. ALARA approach: EPR2 Optimized Collective Dose: EPR2 ongoing optimization work (1/2)

- **Thermal insulation installation/removal**
  - Clear identification of thermal insulation parts and associated pipes
  - Operation with water in the pipes (shielding)
- **Site Logistics**
  - Fast mounting/dismounting scaffolding
  - Supports (e.g. eye hooks) to ease installation of temporary shielding
- **Waste conditioning**
  - Waste selection near their production location
- **Reactor pressure vessel outage activities**
  - Management of pool water levels to maximize shielding during RPV internals or fuel assembly handling underwater (low dose rates on the service floor at the edge of the pool)
  - Access possible through a doorway at the bottom of the pool (access with personal protective equipment, management of radiological cleanliness near the workplace)

4. ALARA approach: EPR2 Optimized Collective Dose: EPR2 ongoing optimization work (2/2)

Further considerations to lower personnel exposure in operation:

- Taking into account Human Factors, personnel safety and organizational matters at design stage
- Improvements in the design and operation of machines used during an outage (remote control options, improved reliability, improved performance in terms of time)
- Monitoring of activities by qualified personnel from a remote room (PSPR) and use of decision-making tools (CADOR) for the radiation protection of workers during operating life of the plant

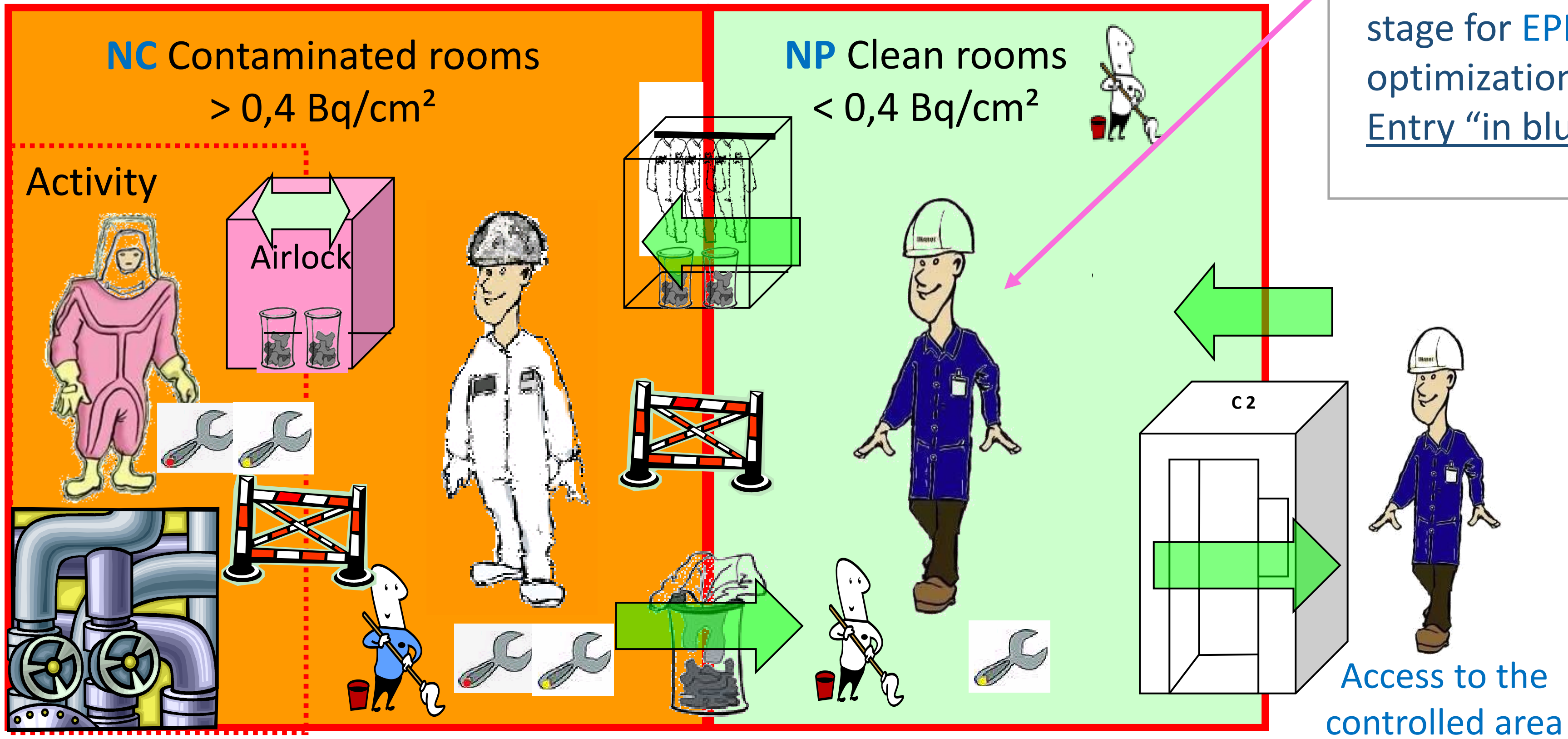
5. EPR2 cleanliness/waste zoning as a tool for optimization

- **Goal of "cleanliness/waste" considered at design stage:**
  - To get a radiological cleanliness at the best international operators level
  - To adapt the protection to the contamination risk; limit the contamination at its source
  - To facilitate the access and working conditions in the radiation controlled area
  - A mean to progress in the plant cleanliness: as the zoning has to be maintained

- **Cleanliness/waste zoning requirements at design:**
  - Identification of the nuclear / conventional areas (**N vs K**) -> Regulatory requirement
  - Evaluation of the contamination level in the nuclear areas (**NP *(nuclear clean)*, NC *(contaminated)***)

RP requirements for: a) Ventilation routing; b) Contamination containment ; c) Operators access ; d) Equipment

5. Cleanliness/waste zoning and EVEREST EPR2 design objective (2/2)



- **"EVEREST operational approach"** at design stage for EPR2 cleanliness and waste management optimization, i.e.:
  Entry "in blue" in the clean zones of the installation.

With EVEREST: it is at the interface "clean/contaminated" that the worker puts overclothing and adapts his personal protective equipment.

Cleanliness/waste considerations: - reduces the amount of waste sent to Rad waste streams;
- contributes to reducing transfer of contamination outside of the installation.

CONCLUSIONS

- **EPR2 is :**
  - is an optimization of EPR in terms of **constructability, cost and delay** while keeping the same high safety performances;
  - is positioned for renewal of French nuclear fleet and EDF Group NNB export

- **For EPR2 model, designers :**
  - "cascade" "EDF RP Referential", i.e.:
    - *RP regulatory requirements;*
    - *"EDF Generation" requirements;*
    - *EDF RP good practices in terms of layout, CW, systems and equipment;*
  - optimize **plant collective dose at design stage** to be comparable to the best French nuclear plants and internationally;
  - optimize **radiological cleanliness** at the best international operators level and therefore contribute to the reduction of transfer of contamination outside of the installation.

Thank you for your attention