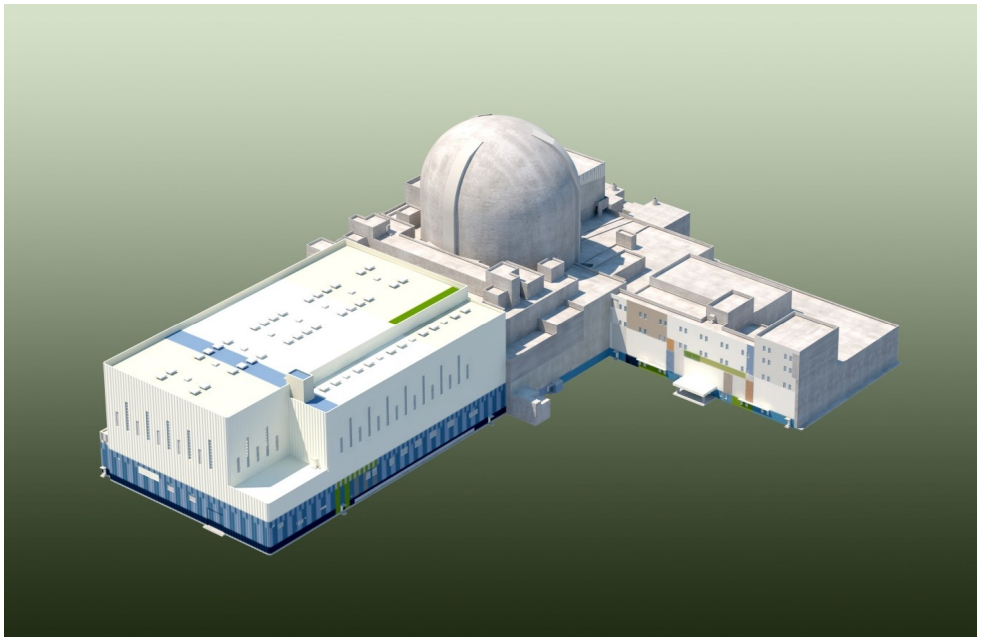
NON-PROPRIETARY

APR1400
Probabilistic Risk Assessment (PRA)



KEPCO/KHNP

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1.1 Regulatory Basis

❑PRA

- **10 CFR 52.47** : Licenses, Certifications, and Approvals for Nuclear Power Plants
  - (a) … must include the following information:
    - (27) A description of the design specific probabilistic risk assessment (PRA) and its results.

- **RG 1.206** : Combined License Applications for Nuclear Power Plants
  - C.I.19 : Probabilistic Risk Assessment and Severe Accident Evaluation
  - To provide prospective COL applicants with guidance concerning the format and content of the application

1.1 Regulatory Basis (Cont'd)

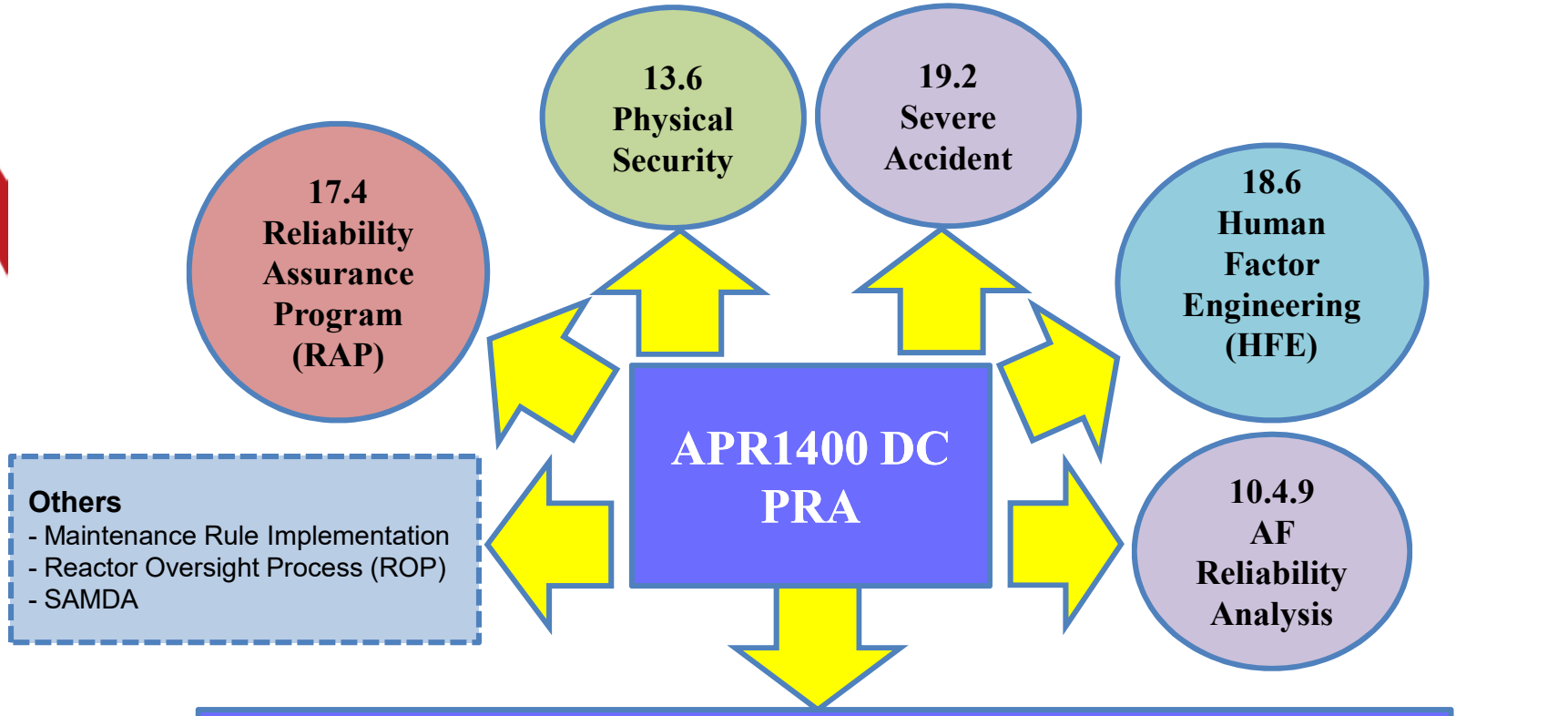
❑ PRA Scope and Quality

- **SRP 19.0 :** Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactor
- **SRP 19.1:** Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities
- **RG 1.174 (Rev. 2):**An Approach for using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis
- **RG 1.200 (Rev. 2):** An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment in Risk-Informed Activities
- **DC/COL-ISG-03:** Probabilistic Risk Assessment Information to Support Design Certification and Combined License Applications
- **ASME/ANS RA-Sa-2008/2009 PRA Standards**

1.2 Purpose of APR1400 DC PRA

- To meet 10 CFR 52.47 (a) (27)
- To identify and address potential design features and operational vulnerabilities
- To reduce or eliminate the significant risk contributors of existing operating plants that are applicable to the new design by introducing appropriate features and requirements
- To serve as a tool used to improve the design to reduce or eliminate the significant risk contributors
- To demonstrate that the risk associated with the design is acceptably low compared to the nuclear regulatory commission's goals of less than 1×10^{-4}/year for core damage frequency (CDF) and less than 1×10^{-6}/year for large release frequency (LRF).

1.3 Application of APR1400 DC PRA



1. PRA is an integral part of the design process.
2. PRA is used to optimize the plant design

Decision Making Tool to optimize the plant design with respect to safety in design stage

Risk Impact Check for design changes by RAI Responses

1.4 Documents of APR1400 DC PRA

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1.4 Documents of APR1400 DC PRA (Cont'd)

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1.4 Documents of APR1400 DC PRA (Cont'd)

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1.4 Documents of APR1400 DC PRA (Cont'd)

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2. APR1400 DC PRA

2.1 Design Features of APR1400 (PRA)

2.2 Scope

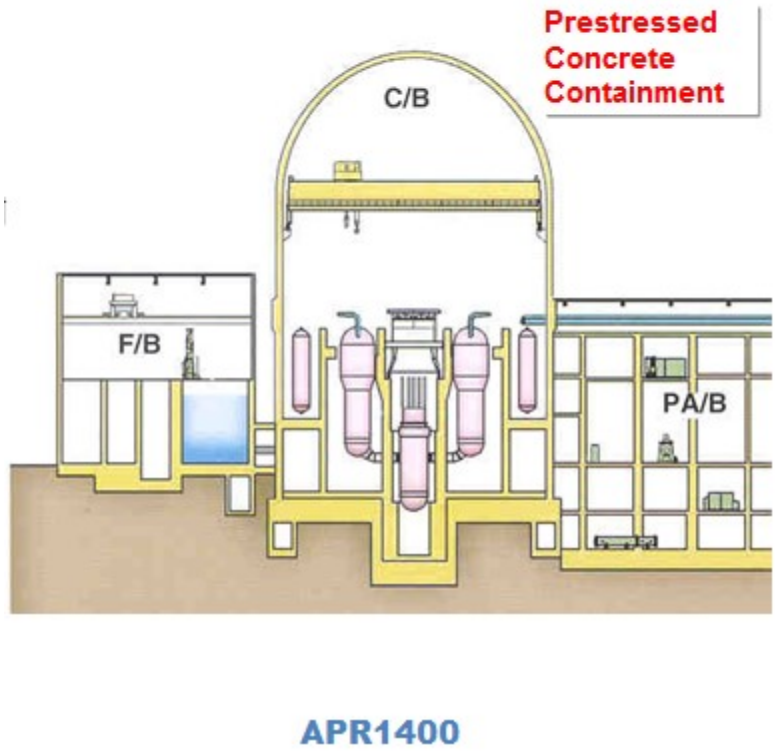
2.3 Methodology

2.4 PRA Code Package

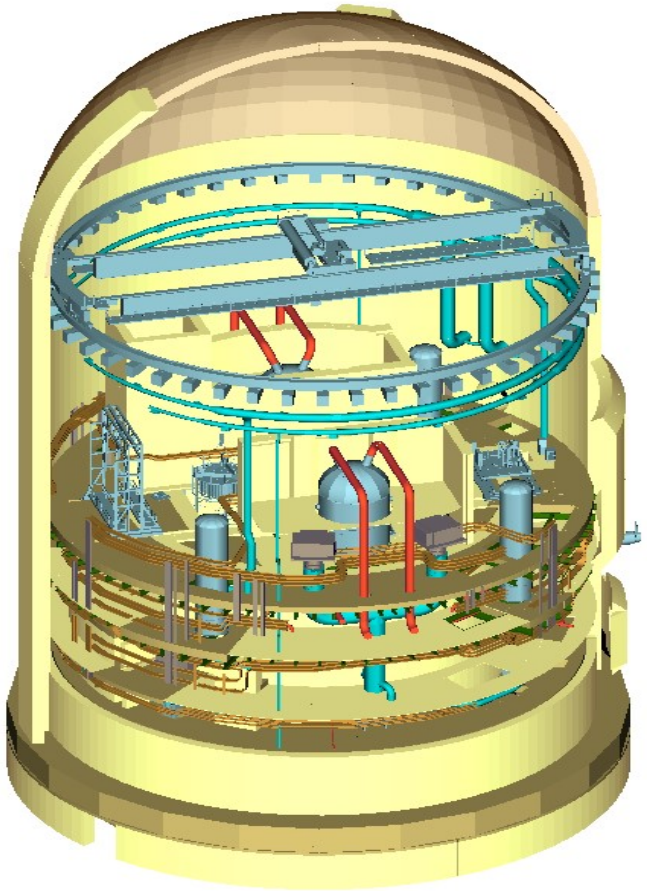
2.5 PRA Results and Insights

2.1 Design Features (PRA)

- **Prestressed concrete cylindrical containment**

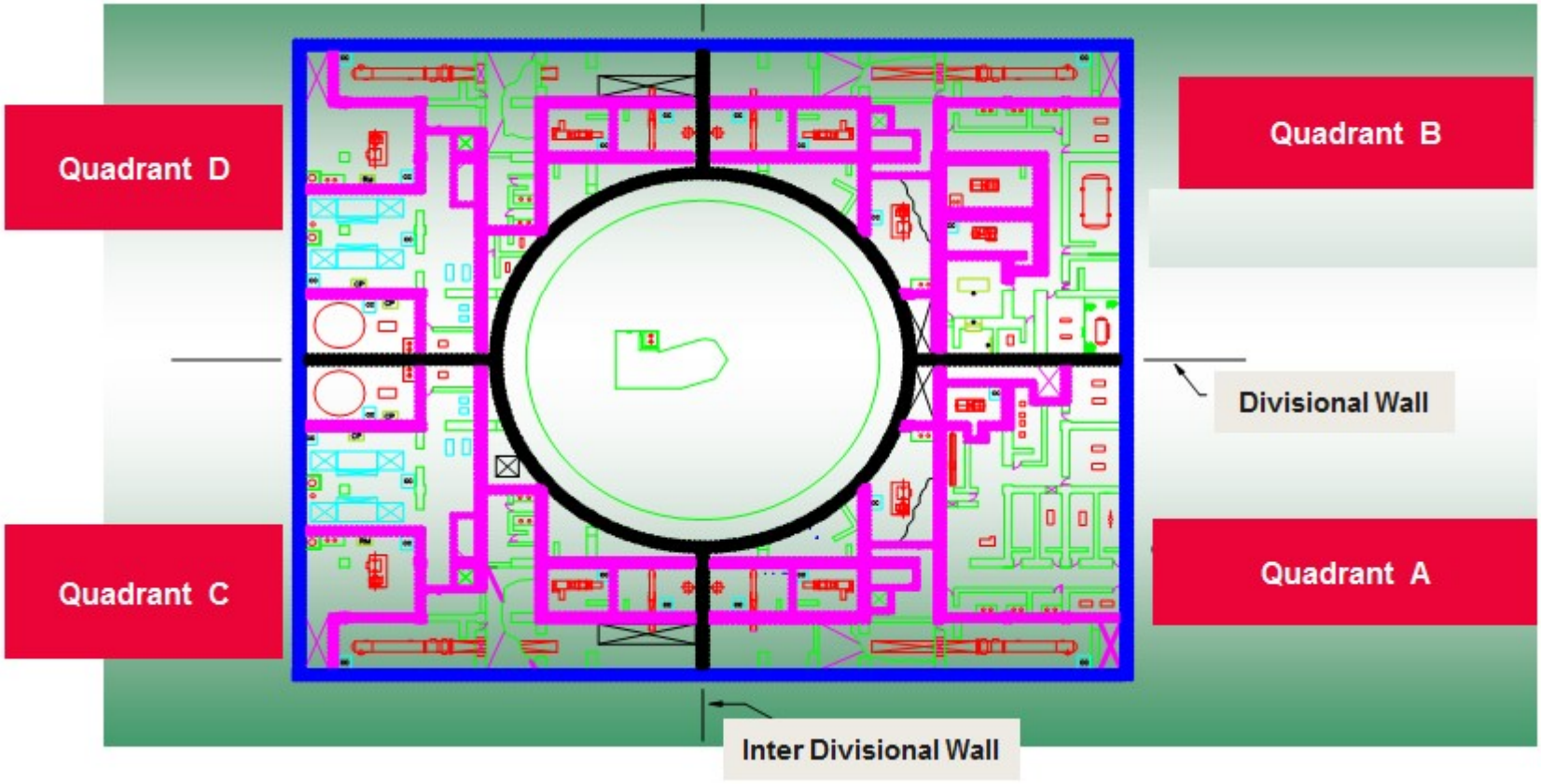


APR1400



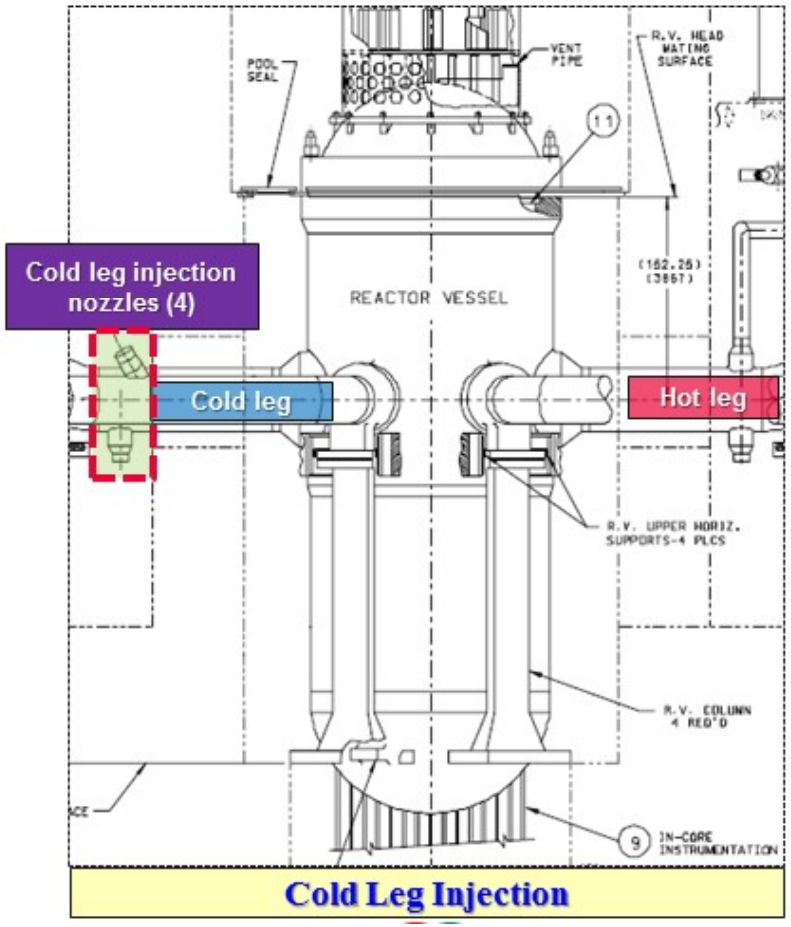
2.1 Design Features (PRA) (Cont'd)

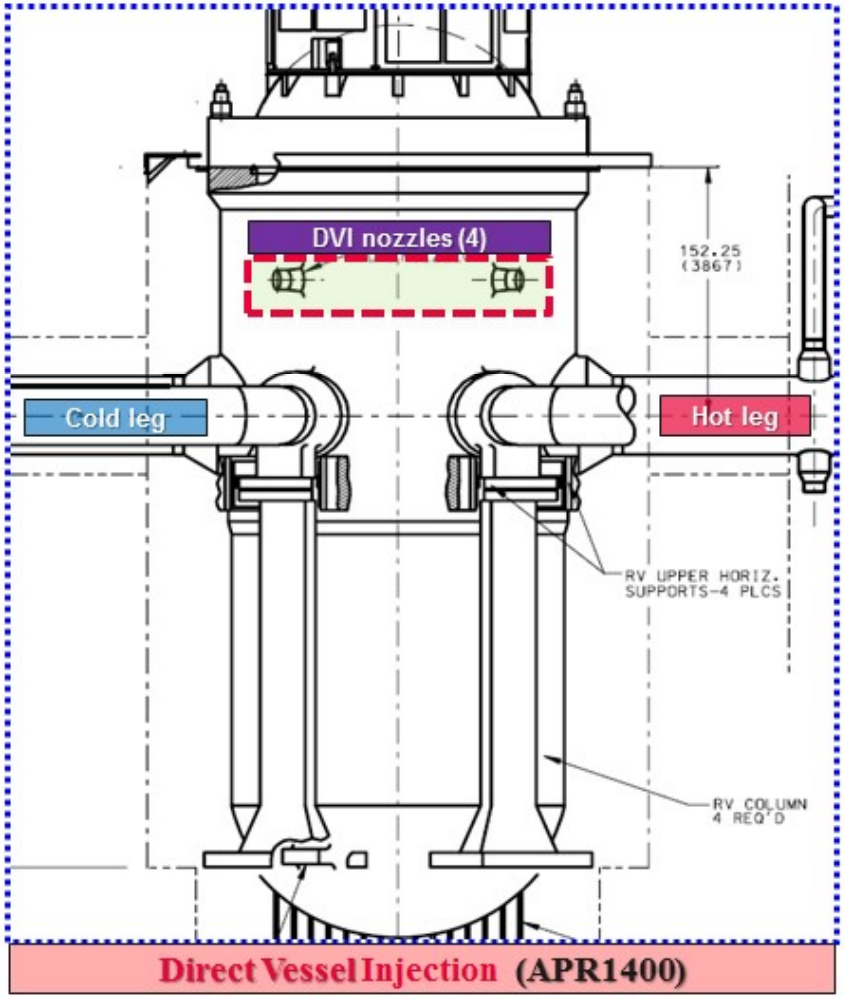
❑ Quadrant Design of Auxiliary Building



2.1 Design Features (PRA) (Cont'd)

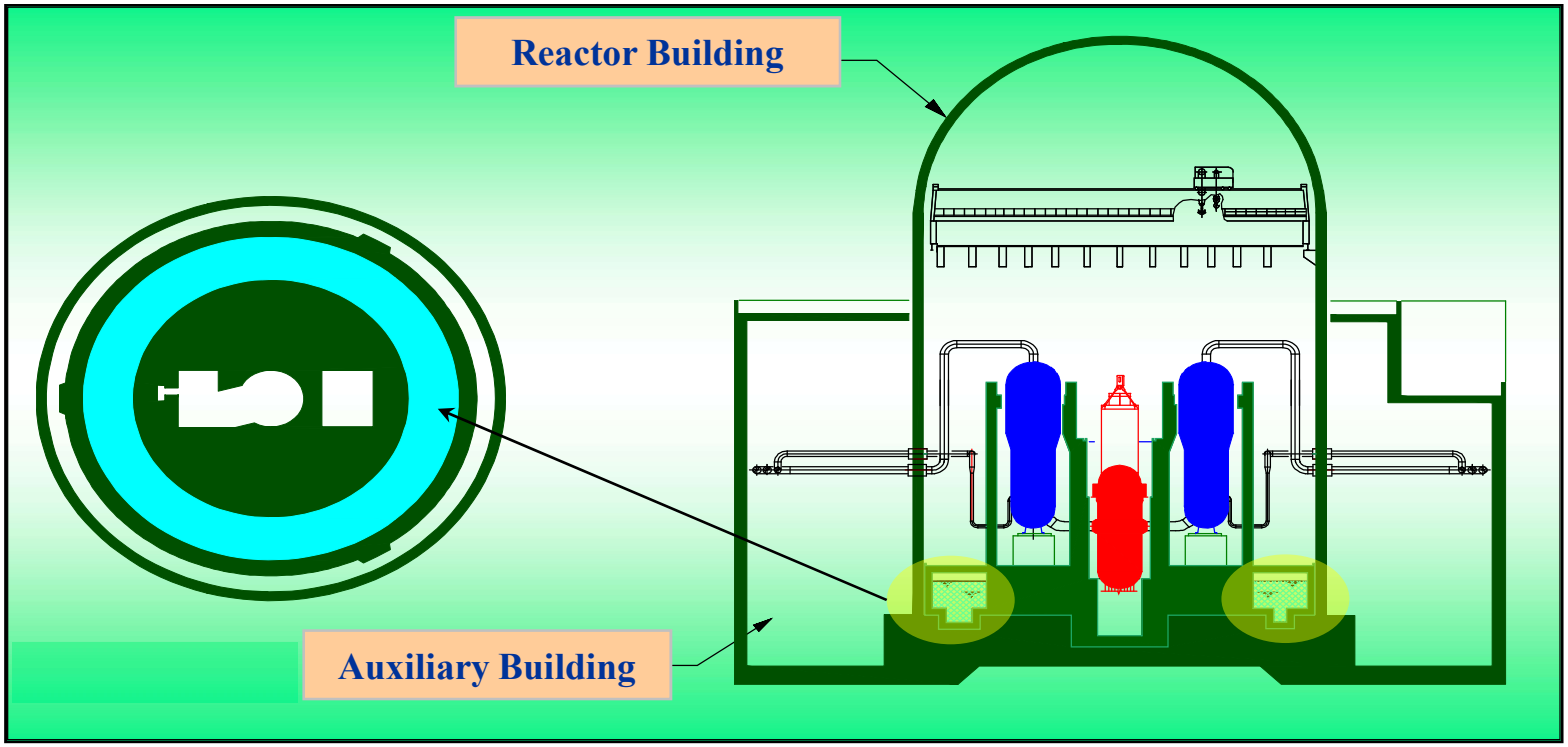
❑ Direct Vessel Injection





2.1 Design Features (PRA) (Cont'd)

❑ In-Containment Refueling Water Storage Tank (IRWST)



2.1 Design Features (PRA) (Cont'd)

❑ Digitalized I&C System and Advanced MCR

- Fully Digitalized and Advanced Control Room with Analog Backup devices
- Compact workstation type
  - ➢ High fidelity data processing
  - ➢ Enhanced operating flexibility
- Soft Console (touch screen)
  - ➢ Emulate the physical switches and analog control devices
- Large Display Panel (LDP)
  - ➢ Integrated control and indication
- Safety Console
  - ➢ Dedicated Analog Backup Switches
- Remote Shutdown Console (RSC)

2.2 PRA Scope

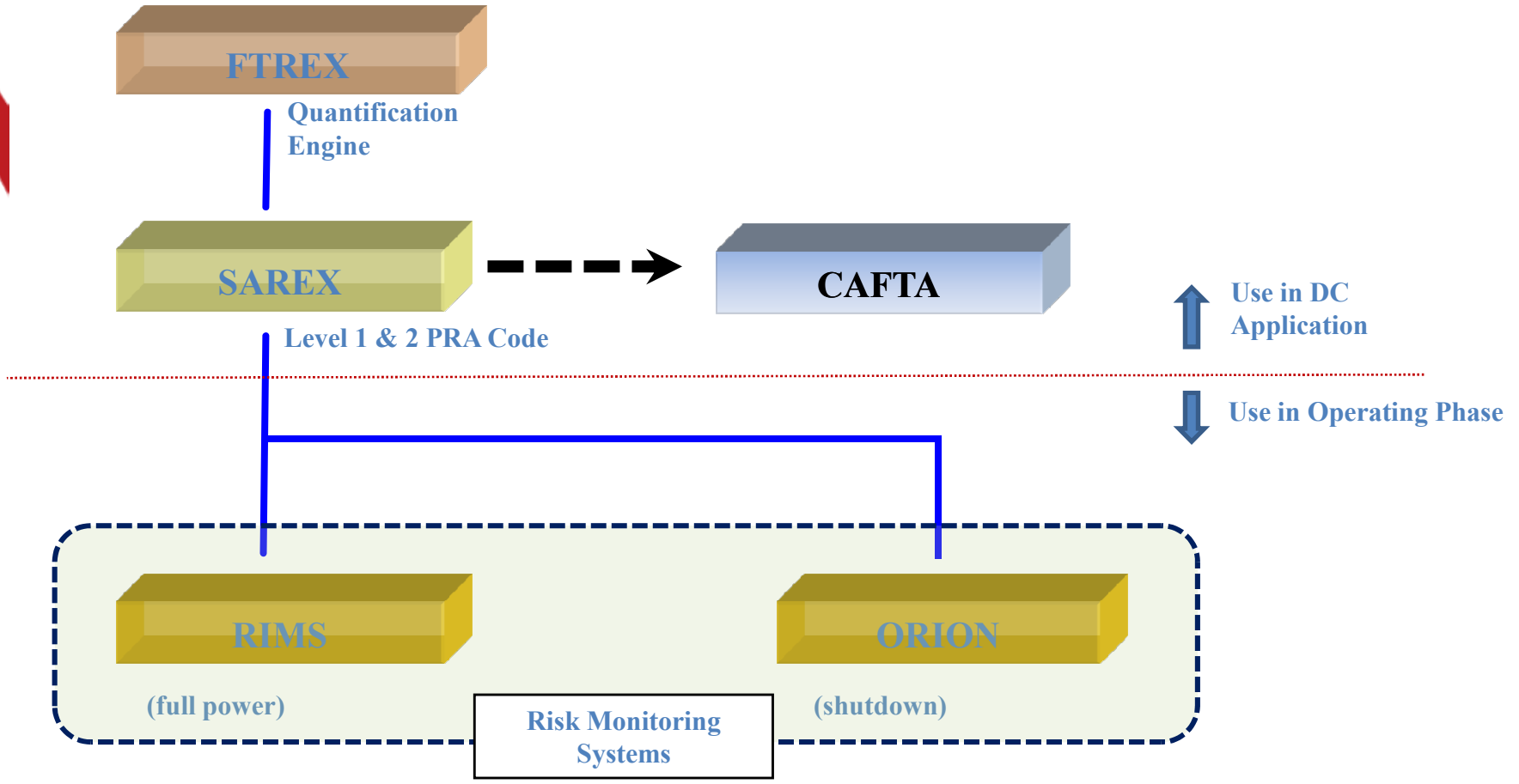
Operation Mode	Hazard	Level 1 (CDF)	Level 2 (LRF)
Full power	Internal Events	O	O
	Internal Fire	O	O
	Internal Flooding	O	O
	Seismic*	O	O
Low Power and Shutdown (LPSD)	Internal Events	O	O
	Internal Fire	O	O
	Internal Flooding	O	O
	Seismic**	△	△
	Other External	O	O

*) PRA-based SMA, **) It will be added in the DCD 19.1.

2.3 PRA Methodology

- **NUREG/CR-2300**, PRA Procedures Guide : U.S. Nuclear Regulatory Commission
- **NUREG/CR-1150**, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants
- **NUREG/CR-6850** : EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities
- **NUREG/CR-7114**: A Framework for Low Power/Shutdown Fire PRA
- **ANS/ASME-58-22-2013 (draft):** Low Power and Shutdown PRA Methodology
- **ASME/ANS RA-Sa-2008/2009**, PRA Standards

2.4 PRA Code Package



2.5 PRA Results and Insights

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2.5 PRA Results and Insights (Cont'd)

- **Risk insights included information about :**
  - Design features that are the highly effective in reducing risk with respect to operating plants
  - Major contributors to risk, including equipment failures and operator actions
  - Major contributors to the uncertainty associated with the risk results

- **Table 19.1-4 (DCD 19.1)** is a list of significant PRA insights and regarding how the design and operational features affect the plant risk, and how uncertainties affect the PRA models in representing the plant risk.

  - The in-containment refueling water storage tank (IRWST) is an important design feature that helps reduce the risk with respect to currently operating reactor designs.
  - All fire barriers that provide separation between the two divisions are rated for at least 3 hours.
  - Flood protection is integrated into the auxiliary building floor drainage systems. The flood drainage systems are separated by quadrants with no common drain lines between the quadrants.
  - The fire engine truck as ECSBS pumping device is used to deliver water from external water sources to the ECSBS containment spray header after the initiation of a severe accident.

2.5 PRA Results and Insights (Cont'd)

- **Risk insights from each hazard evaluated for different operational modes are described in the subsections as follows:**
  - **19.1.4.1.2.8 – Level 1 Internal Events PRA for Operations at Power**
    - The CDF is low enough to meet the commission's goals.
    - The CDF is dominated by LOOP/SBO initiating events (approximately 39%), but total CDF of LOOP/SBO is small at less than 1.5E-07/yr, which is a result of the high redundancy in trains and diversity in emergency power supplies.
  - **19.1.4.2.2.8 – Level 2 Internal Events PRA for Operations at Power**
    - The LRF is low enough to meet the commission's goals
    - ECSBS is the important system in maintaining an intact containment.
  - **19.1.5.2.2.5 – Internal Fire Risk Evaluation**
    - The CDF/LRF from internal fire is low, because APR1400 has a strong design features that promote reduced fire risk.
      (1) The auxiliary building is divided into four quadrants, and each quadrant contains the equipment for a safety train.
      (2) The highly compartmentalized auxiliary building is made up of many fire areas with 3-hour fire rating barriers to minimize the impact from any single fire in the auxiliary building.

2.5 PRA Results and Insights (Cont'd)

- **19.1.5.3.2.4 – Internal Flooding Risk Evaluation**
  - The CDF/LRF from internal flooding is low, because APR1400 has a strong design features that promote reduced flooding risk.
  - It may be attributed primarily to the following factors:
    (1) effective separation of divisions, for the SC pumps and their power supplies, via flood barriers.
    (2) the large emergency overflow lines (EOLs),which serve as high capacity drains.

- **19.1.6.1.2.8 – Level 1 Internal Events PRA for LPSD Operations**
  - The most dominant contributor to the total CDF.
  - Many systems are manually started or aligned during shutdown modes. Thus, training is especially important for shutdown evolutions because operator error is often a significant risk contributor in shutdown sequences.

- **19.1.6.2.2.7 – Level 2 Internal Events PRA for LPSD Operations**
- **19.1.5.3.2.5 – Internal Fire PRA for LPSD Operations**
- **19.1.5.4.2.7 – Internal Flooding PRA for LPSD Operations**

3. Summary

3. Summary

- **The results of APR1400 DC PRA show that the APR1400 design has a low level of risk and meets the CDF, LRF and containment performance goals.**
  - It is a good enough value to meet the NRC safety goals.
  - The PRA results and insights confirmed that the APR1400 design has evolved from current PWR technology that incorporates features intended to make the plant safer and easier to operate as compared to currently operating plants.
- **The APR1400 DC PRA has been effectively used to achieve**
  1) to identify potential design and operational vulnerabilities,
  2) to reduce or eliminate weaknesses of existing operating plants,
  3) to select among alternative features, operational strategies, and design option, and
  4) to examine the risk significance of specific human errors associated with the design, and characterize the significant human errors in preparation for better training and more refined procedures.