中核集团 CNNC

Advanced Active & Passive PWR

HPR1000 Overview

Sao Paulo, Brazil

Oct, 2015

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- Overview
- Design Characteristics
- Proven Technology
- Engineering Progress
- Summary

1. Overview

☐ Roadmap of PWR Domestically-development & Oversea-introduction

Construction of the 1st NPP (300MW PWR)

Construction of 650 MWe NPP CNP600

Construction of CNP1000

R&D of CP1000

HPR1000

Introduction of Daya Bay NPP

Introduction of LingAo NPP

Introduction of VVER

Introduction of EPR

Introduction of AP1000

1. Overview

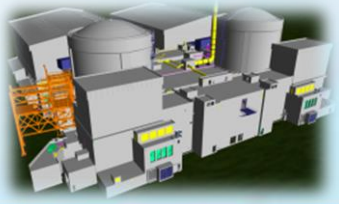
Roadmap of HPR1000 R&D

1999

CNP1000

Gen II+

- 157 FAs in reactor core
- Twin-unit layout
- Single containment



2007

CP1000

Gen III-

- 177 FAs in reactor core
- Single-unit layout
- D.-shell containment
- Other 19 improvements

2010's

HPR1000

Gen III+

- Active + passive safety systems
- SA countermeasures
- Protection against external hazards
- Fukushima feedbacks
- Latest safety requirement

1. Overview

3rd Generation PWR

Satisfying latest nuclear safety codes and standards with advanced technology

3 Design Features

- 177-fuel-assembly core
- Single unit layout
- Double shell containment

3 Active + Passive Systems

- Residual heat removal from secondary side
- Containment heat removal
- Cavity injection and cooling

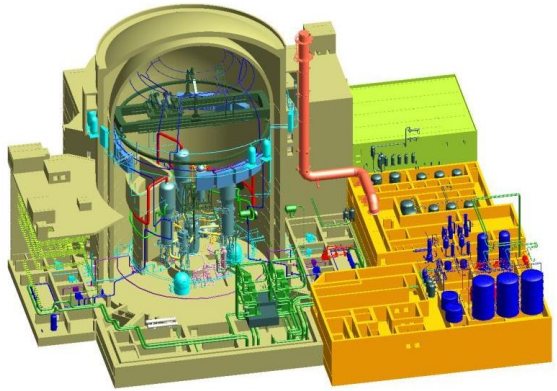
3 Enhanced Protection Capabilities against

- Seismic
- Commercial aircraft crash
- Plant emergency

2. Design Characteristics

General Parameters

Reactor core thermal output	3050 MWt
Nominal power	⩾1150 Mwe
Design life	60 years
Fuel assembly number	177
Refueling cycle	18 months
Average Availability	⩾ 90%
Nuclear island layout	Single-unit
Containment	Double-shell



2. Design Characteristics

General Parameters

Safe shutdown earthquake (SSE)	0.3g
Load Following Capability	Yes
Operator nonintervention period	30 mins
Plant autonomy	72 hours
Occupational exposure dose	<1 m·Sv/reactor year
safety systems concept	Active+Passive
CDF	$<10^{-6}$
LRF	$<10^{-7}$
Deployment site	Fuqing, Fujian

2. Design Characteristics

Design Safety Principles

- HPR1000 design follows the "Defense-in-Depth" fundamental principles
- The redundancy, diversity and independency of SSCs have been improved significantly.
- Integrated application of "active and passive safety measures" for prevention and mitigation of accident, which can ensure the fulfillment of three Fundamental Functions and avoid the large release of radioactive materials in practice.
- 30min nonintervention-72hours autonomy-long-term EP

2. Design Characteristics

Fundamental Safety Functions Realization

Fundamental Safety Functions

2. Removal of decay Heat

- Safety Injection System
- Auxiliary Feedwater System
- Atmospheric Steam Dump System
- Passive Residual Heat Removal System of Secondary Side
- Feed & Bleed
- Reactor Cavity Injection and Cooling System
- Temporary water makeup for the primary and secondary loop

1. Control of Reactivity

- Control rod
- Reactor Protection System
- Chemical and Volume control system
- Emergency Boron Injection System

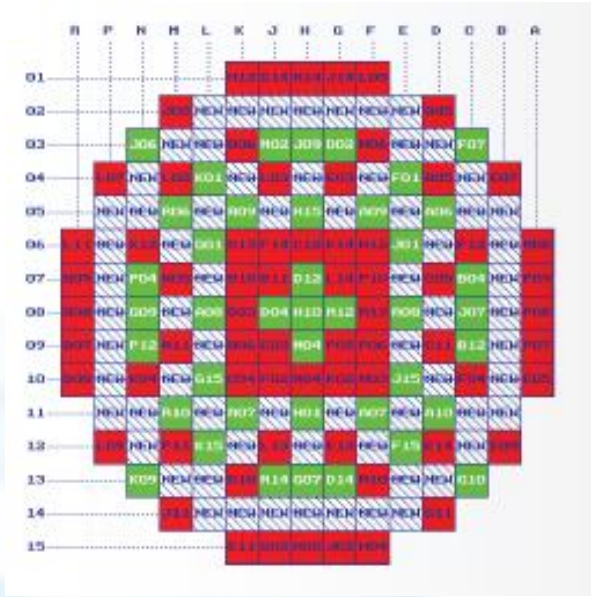
3. Confinement of radioactive materials

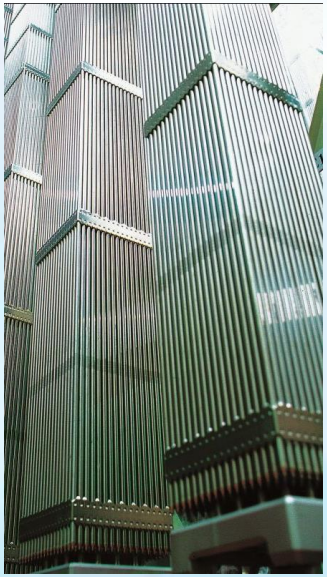
- Double-shell containment
- Containment Isolation System
- Containment Spray System
- Passive Containment Heat Removal System
- Containment Hydrogen Removal System
- Containment Filtration and Exhaust System

2. Design Characteristics

☐ Reactor Core

- 177 fuel assemblies, with lower liner power density to ensure sufficient core thermal-hydraulic margin
- Low leakage fuel loading scheme



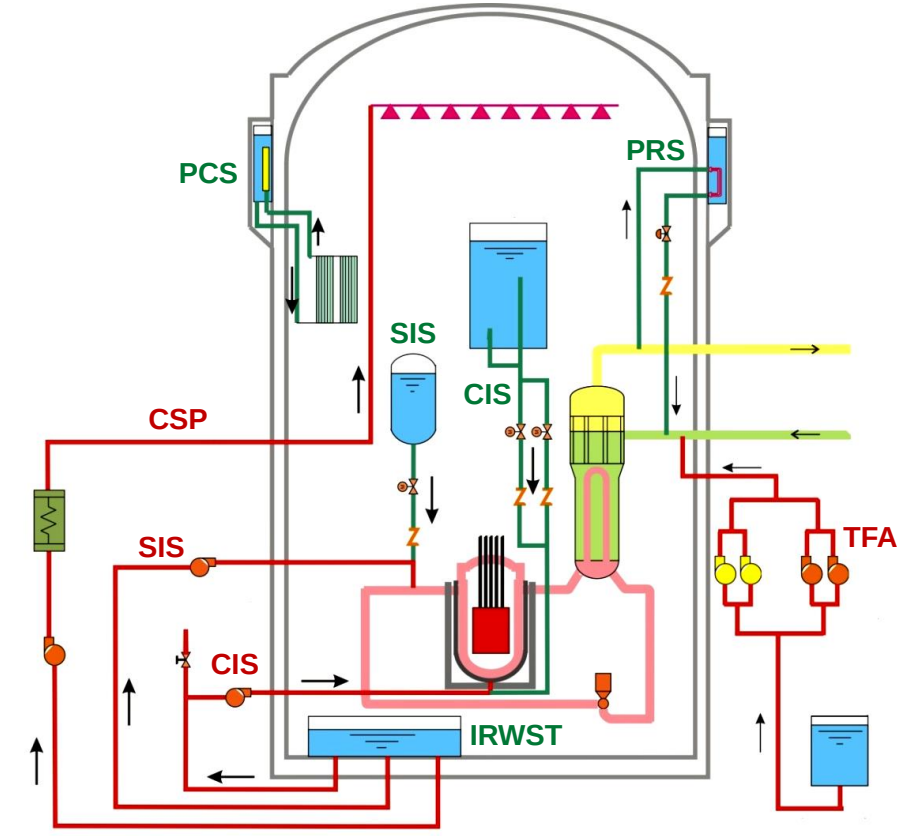


- Advanced fuel assemblies, with refueling cycle of 18 months
- Advanced in-core instrumentation

2. Design Characteristics

☐ Active + Passive Safety Design

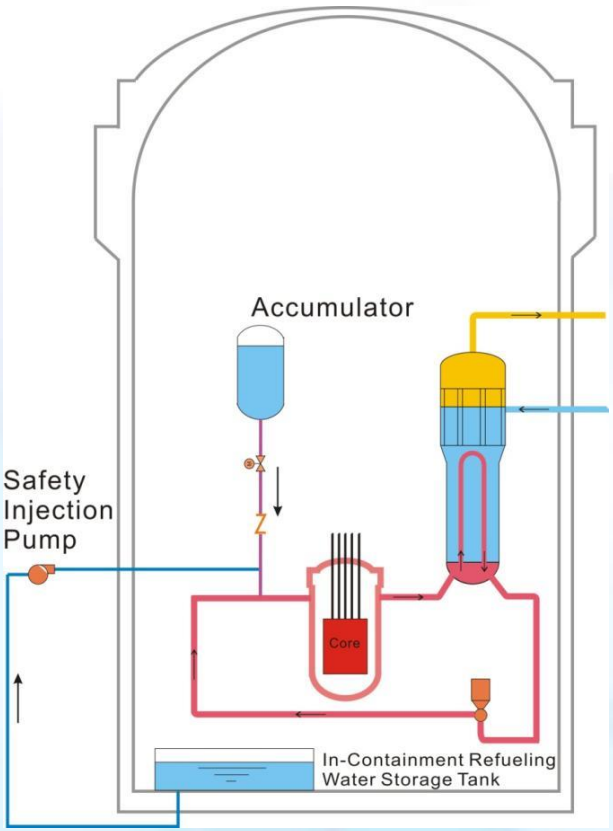
- Active: proven and reliable
- Passive: no need for power
- Active + Passive: diverse approaches to perform safety function
  - ✓ Emergency core cooling
  - ✓ Core residual heat removal
  - ✓ Cavity flooding and cooling (IVR)
  - ✓ Containment heat removal



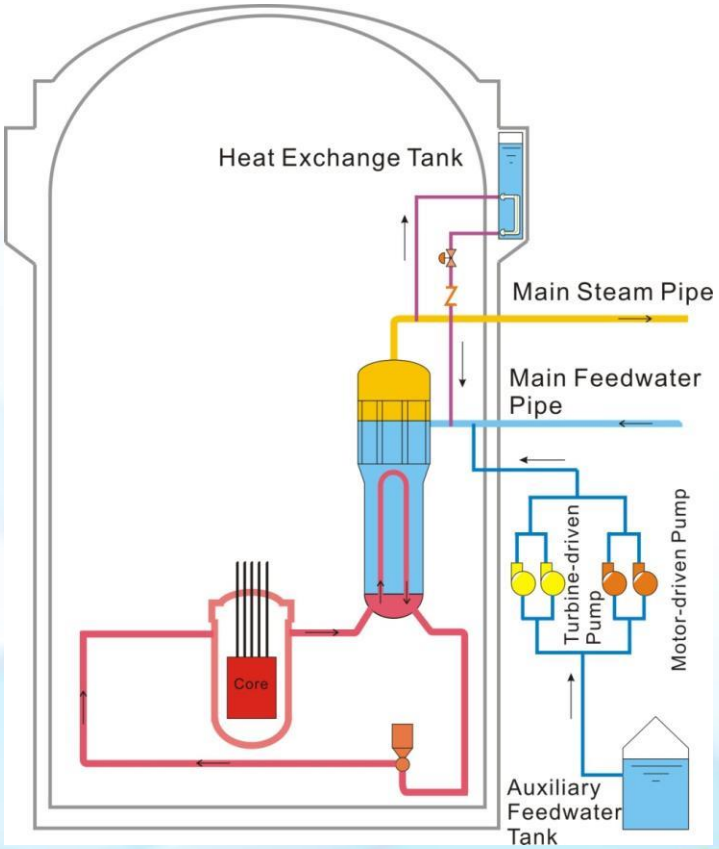
Red: active Green: passive

2. Design Characteristics

☐ Emergency core cooling

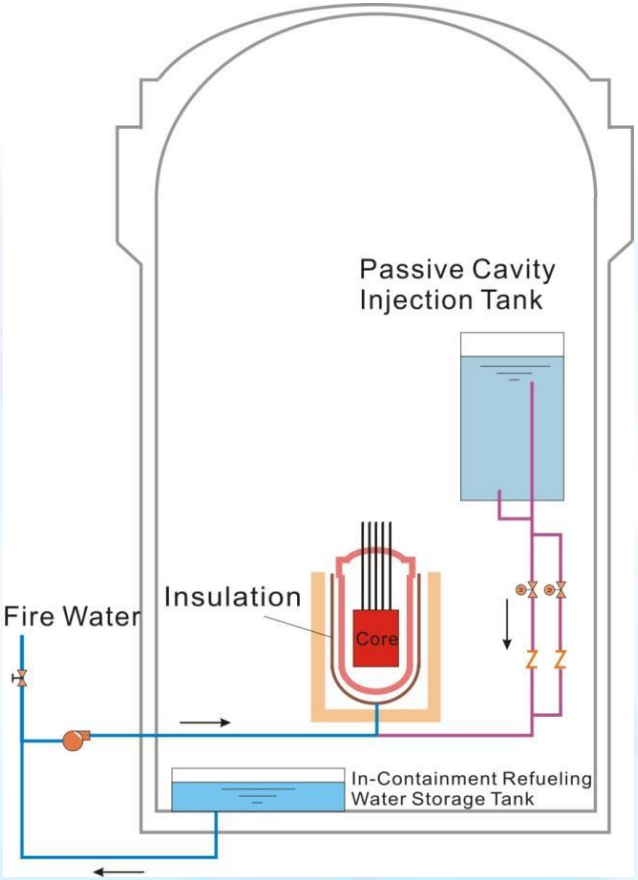


☐ Core residual heat removal from SG shell side

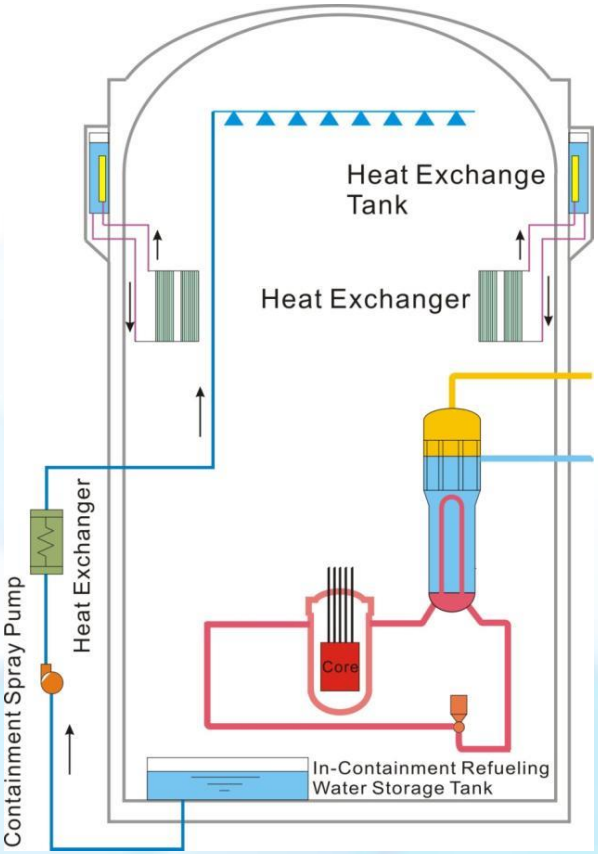


2. Design Characteristics

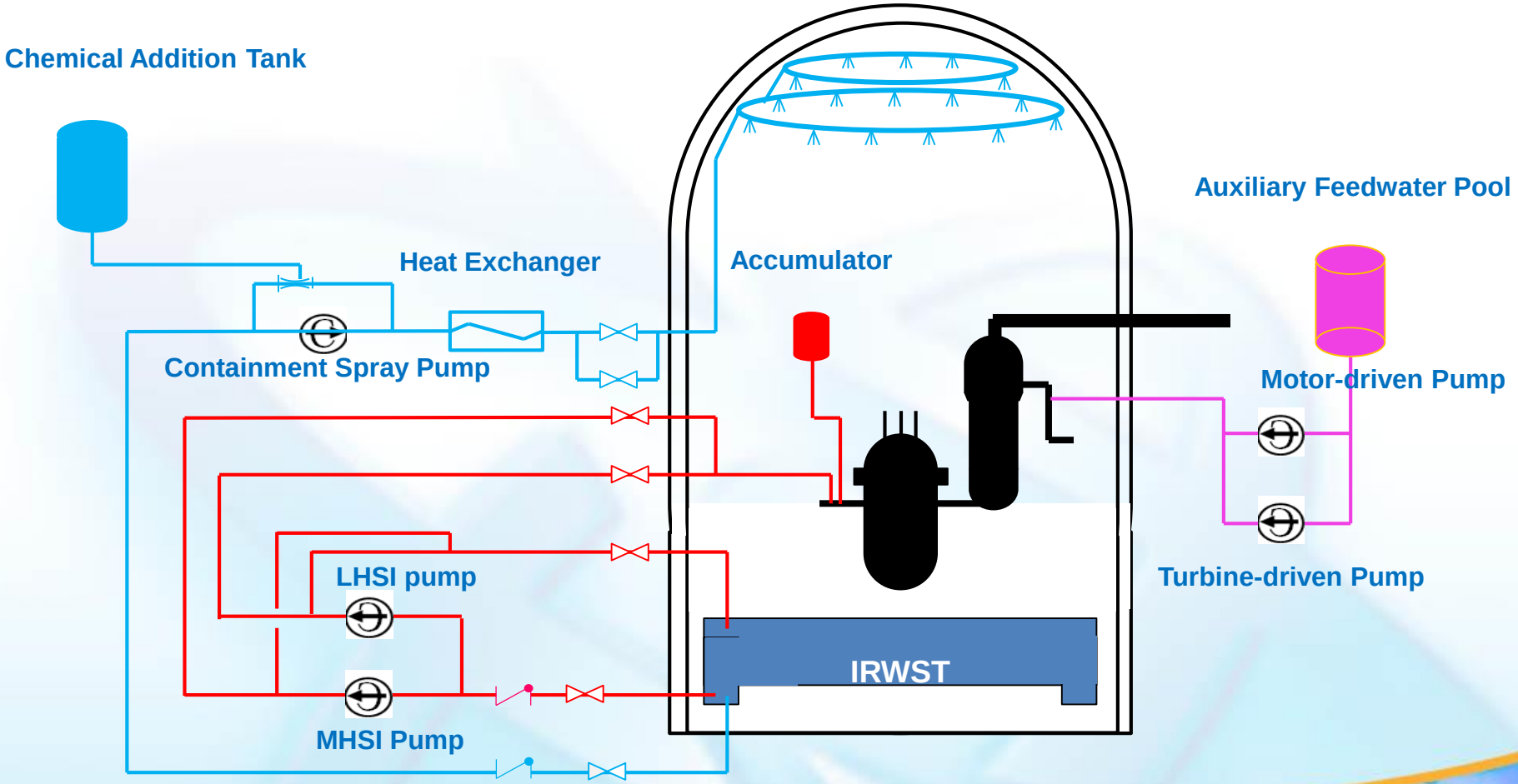
Cavity flooding and cooling (IVR)



Containment heat removal

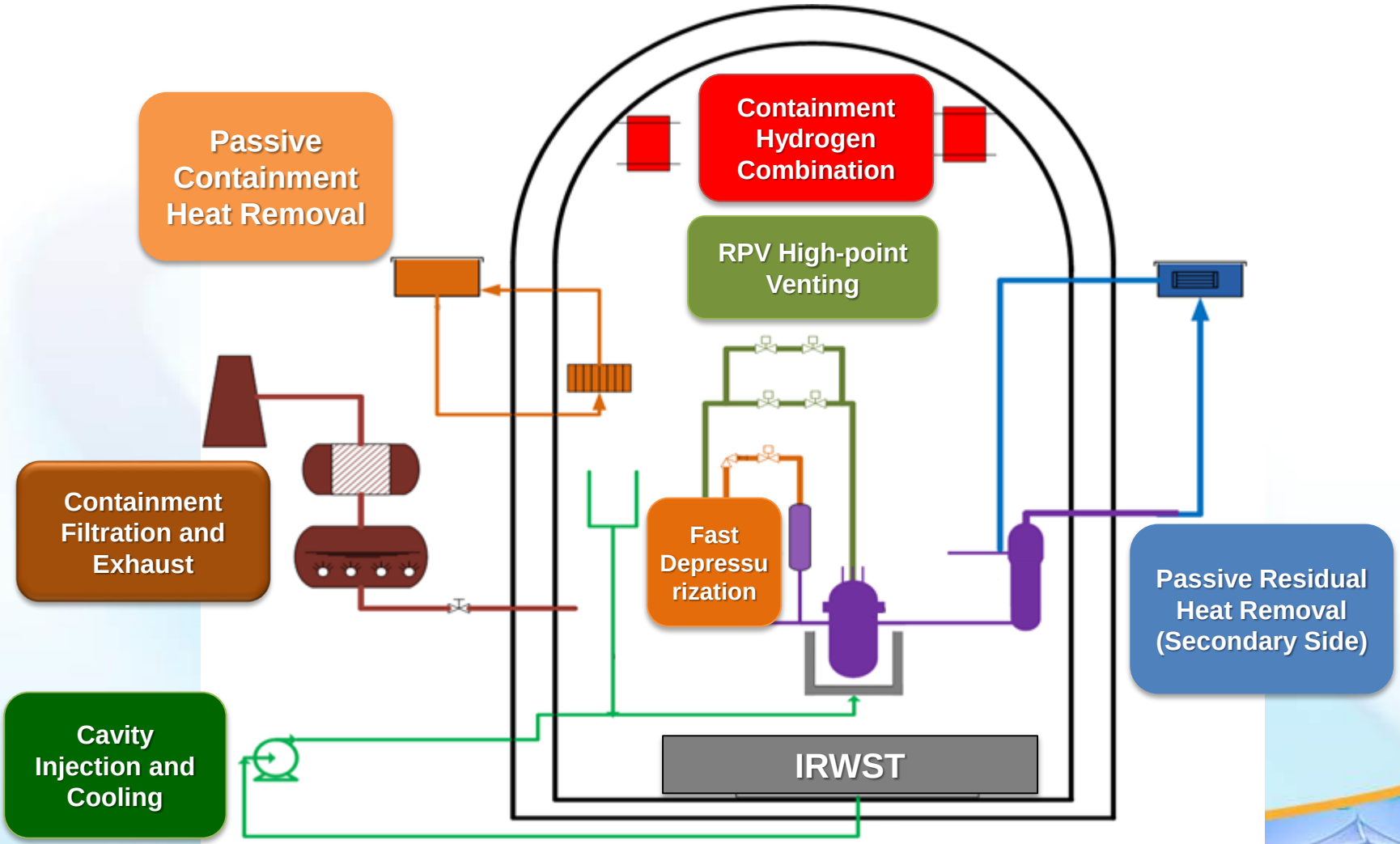


Engineered Safety Features



2. Design Characteristics

BDBA/SA Prevention & Mitigation Measures



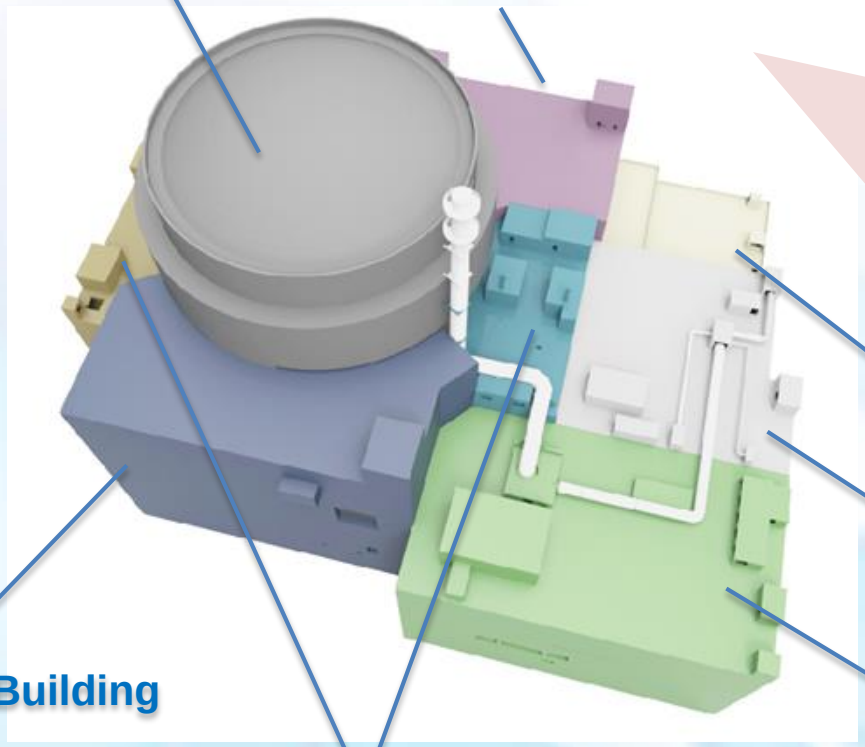
2. Design Characteristics

BDBA/SA Prevention & Mitigation Measures

	Phenomena	Countermeasures
Containment Failure	Hydrogen detonation	Containment Hydrogen Combination System
	High pressure molten corium ejection, DCH	Fast Depressurization System for RCS
	Long term overpressure	Passive Containment Heat Removal System, Containment Filtration and Exhaust System
	Basement melt-through	Reactor Cavity Injection and Cooling System
	Station blackout	Passive systems, Diverse power sources
	Other	RPV High-point Venting System, Habitability Design of Main Control Room, SAMG and etc.

2. Design Characteristics

NI building: Single unit layout



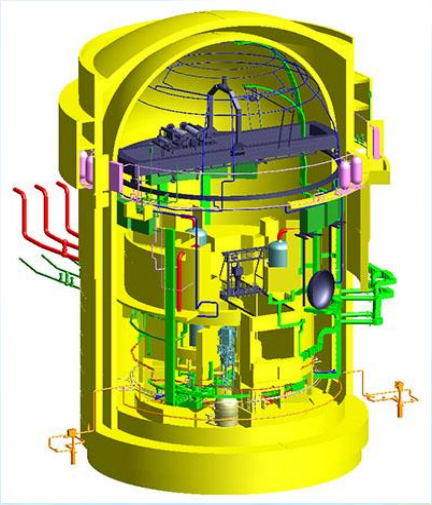
Benefits of single unit layout

- Providing physical separation, reducing interaction between units
- Convenient for plant construction, operation and maintenance
- More flexible for plant siting

2. Design Characteristics

NI building: Double Shell Containment

- Inner shell: prestressed reinforced concrete with a leak-tight steel liner inside
- Outer shell: reinforced concrete structure
- Annular space: keeping negative pressure, collection and filtration of the leak



- Large free volume: >80,000 m^3
- long lifetime: 60 years
- Withstand external events: large commercial aircraft crash, tornado, missile, explosion and etc.

2. Design Characteristics

☐ Enhanced protection against external events

- Seismic input with peak ground acceleration of 0.3 g
- Protection against Large Commercial Aircraft Crash

✓APC shell protection

(for Reactor Building, Fuel Building and Electrical Building containing MCR)

✓ Physical separation of redundant systems

(for Safeguard building)

2. Design Characteristics

Diversity of Power Sources

Turbine generator
During normal operation

Two trains of independent Off-site power If turbine tripped

Trains of diesel generators for each unit As emergency power

Extra diesel generator

SBO Diesel Generator
In case of SBO

DC Battery: 2hours and 72 hours

2. Design Characteristics

Fukushima Feedback

Additional emergency water makeup and associated interfaces

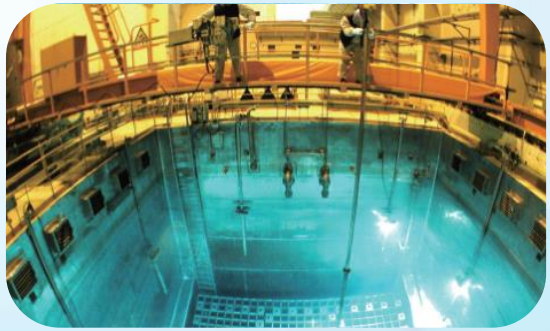
Improvements of power supply: SBO (Station Black Out) generator

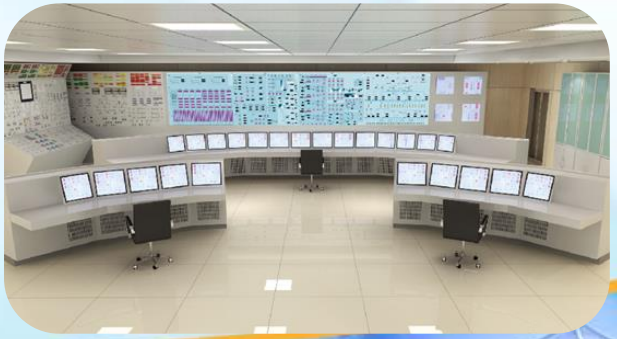
Extension of nonintervention period

More conservative seismic margin

Spent fuel pool monitoring and cooling

Habitability and availability of emergency facilities





2. Design Characteristics

Waste Treatment System

Gaseous Waste

Liquid Waste

Solid Waste

Discharge lower than environmental assessment limit

Final volume < 50 m^3/unit year

Minimization of waste and environmental influences

3. Proven Technology

☐ Based on Proven and Verified Technology

- The configuration and operation of normal operating systems and "**active**" engineered safety features have been validated by long term engineering practice from existing PWR NPPs
- The design concept and technologies adopted for "**passive**" systems have been verified by natural science or specific experiments/tests
- The manufacture and supply capability of almost all key equipments/components is **compatible** with existing NPPs
- Benefiting from rich construction experience and outstanding feedback of operating experience, the construction period and performance of HPR1000 can be ensured

3. Proven Technology

Passive Systems Verification Test

Test of Passive Containment Heat Removal System

Test of Cavity Injection and Cooling System

Passive residual heat removal test for secondary side

3. Proven Technology

Other Verification Tests & Experiments

Flow-induced Vibration Simulation Test of Reactor Internals

Seismic Test of Control Rod Driven Line (CRDL)

Qualification Tests of Electrical Penetration for Double Shell Containment

Aging Test of CRDL

3. Proven Technology

☐ Proven Equipment

HPR1000 is an evolution advanced PWR from the operating NPPs. The equipment supply can rely on the current capability.

Foundry Plant

Machining Plant

Founding RPV head

Forging Plant

4. Engineering Progress

Qualification for HPR1000

Approval of General Design by NEA and NNSA

- HPR1000 general design was approved by NNSA and NEA after the co-review in Aug. 2014.

Approval by State Council, NEA and NNSA

- In Nov. 2014, PSAR review meeting was held by NNSA
- In Nov. 2014, the deployment of HPR1000 to Fuqing Unit 5&6 was approved by NEA.
- In Apr. 2015, HPR1000 Demonstration Project Fujian Fuqing Unit 5&6 was formally approved by the State Council.

4. Engineering Progress

IAEA Generic Reactor Safety Review (GRSR)

- In Apr. 2014, the 'Reactor Safety and Environmental Analysis Report' of HPR1000 was submitted to IAEA;
- In Dec. 2014, HPR1000 passed GRSR with IAEA's positive comments.

Independent Review by NASA

"2012 – Año de Homenaje al doctor D. MANUEL BELGRANO"

NA-SA NUCLEOELECTRICA ARGENTINA S.A. NA-PRE Nº 155/12

Buenos Aires, 22 JUN 2012

Mr. Qian Zhimin
President, China National Nuclear Corporation

I am pleased to inform you that your reactor ACP1000 has been pre-qualified, in replacement of the CP1000, for the Request For Proposals that will be issued soon by Nucleoeléctrica Argentina S.A. for the construction of its Fourth Nuclear Power Plant.

We will be glad to process any enquiries or suggestions you may have about the matter.

Sincerely,

- Approval of Pre-Qualification on HPR1000 general design was issued by Argentina Nuclear Electric Utility (NASA) in Jun. 2012.

GDA qualification by UK agency and regulation

ONR Office for Nuclear Regulation

Environment Agency

- In the future, aims to the GDA qualification in UK

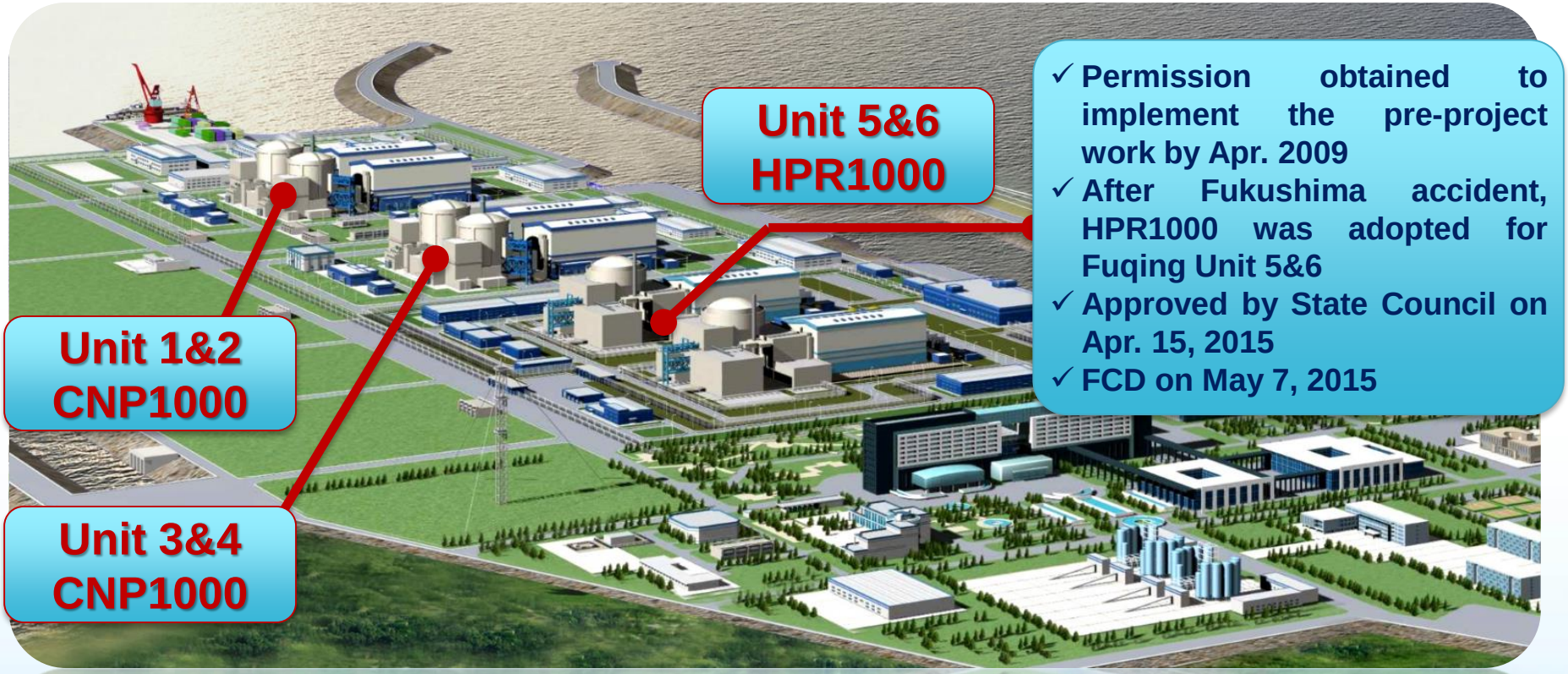
4. Engineering Progress

☐ Demonstration Project Progress

- Contracts for long-lead key equipment have been signed
- FCD was achieved on 7th, May 2015 in Fuqing, China

4. Engineering Progress

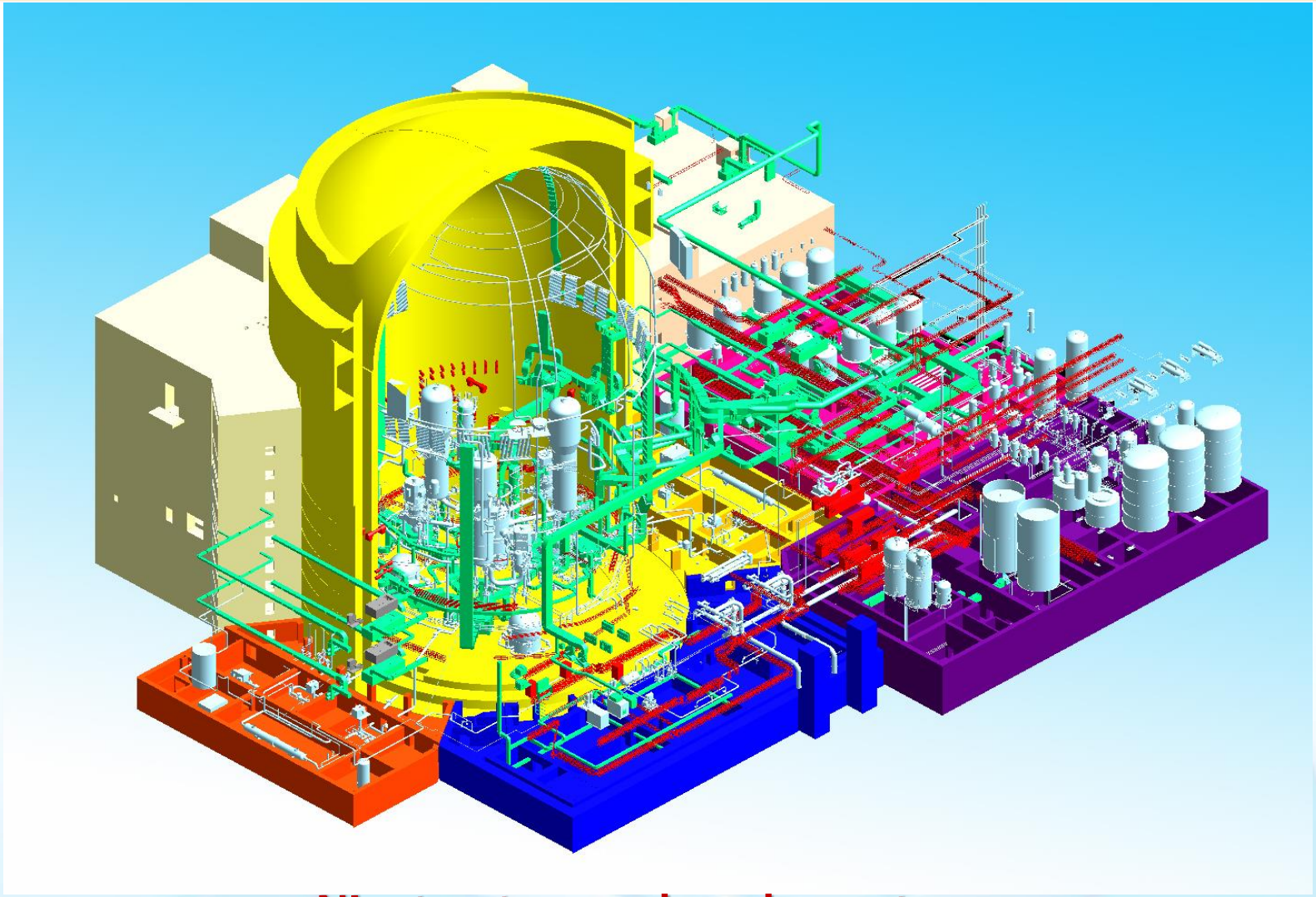
☐ Fuqing NPP Unit 5&6



- ✓ Permission obtained to implement the pre-project work by Apr. 2009
- ✓ After Fukushima accident, HPR1000 was adopted for Fuqing Unit 5&6
- ✓ Approved by State Council on Apr. 15, 2015
- ✓ FCD on May 7, 2015

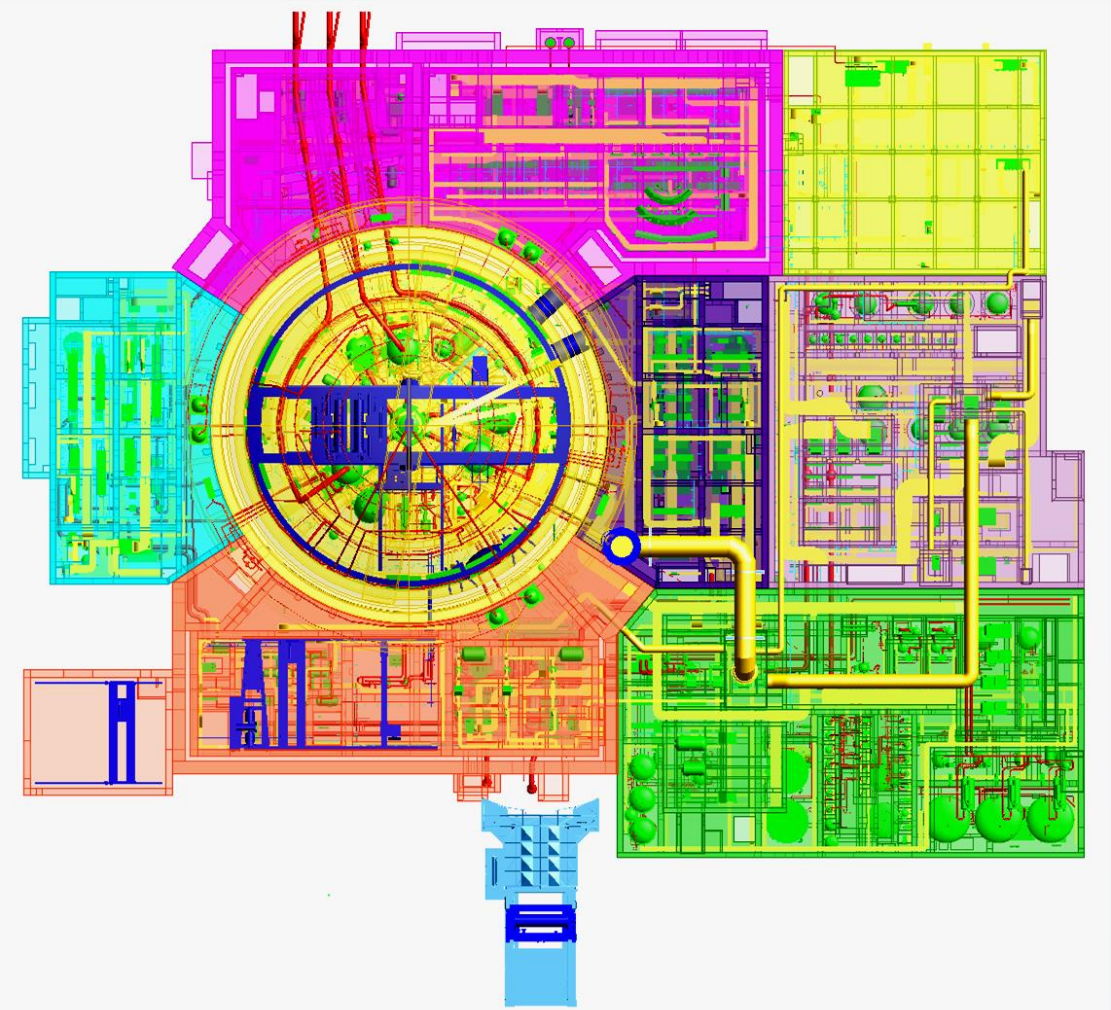
Bird view drawing of Fuqing NPP site

4. Engineering Progress



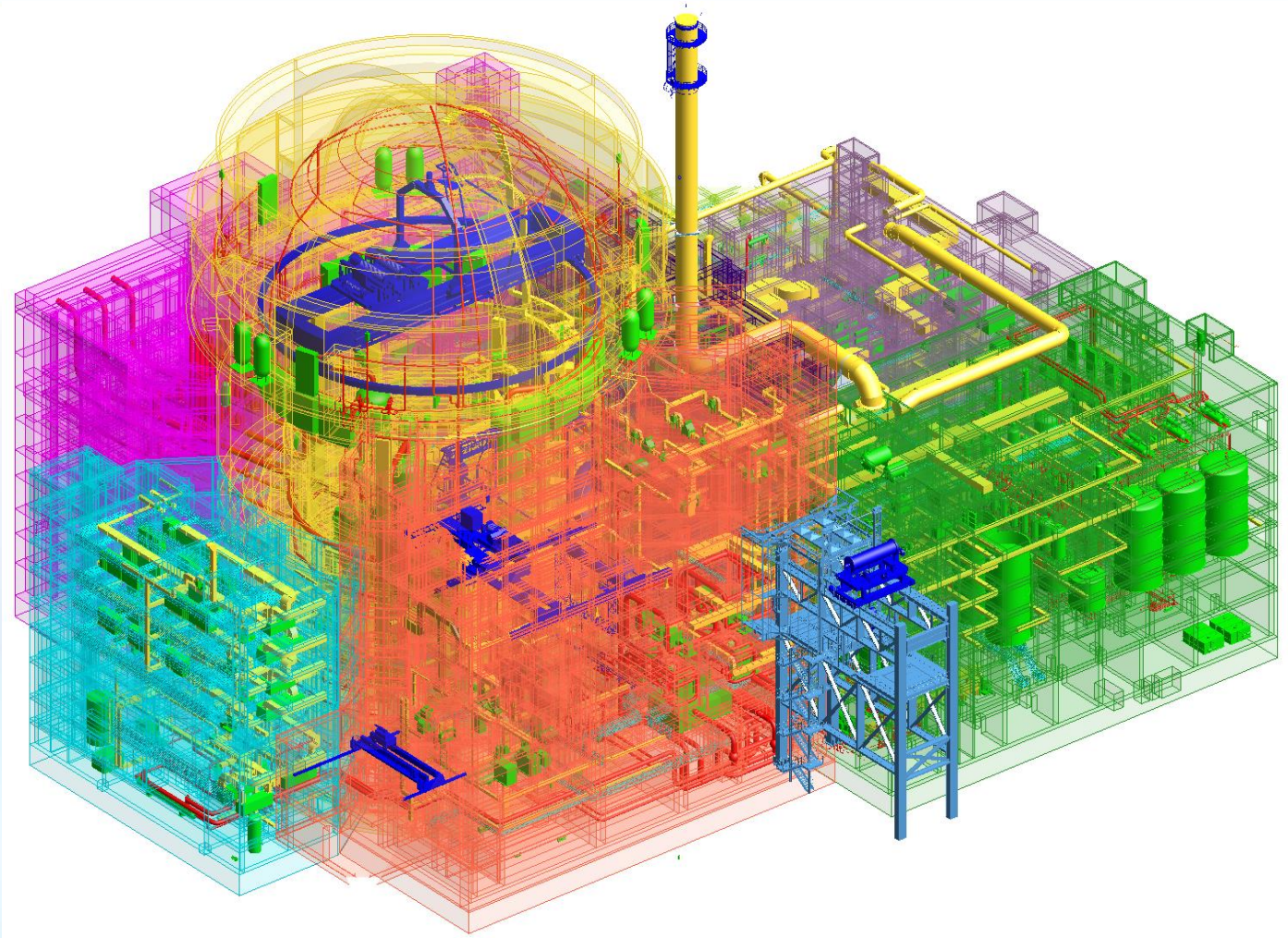
NI: structure and equipments

4. Engineering Progress



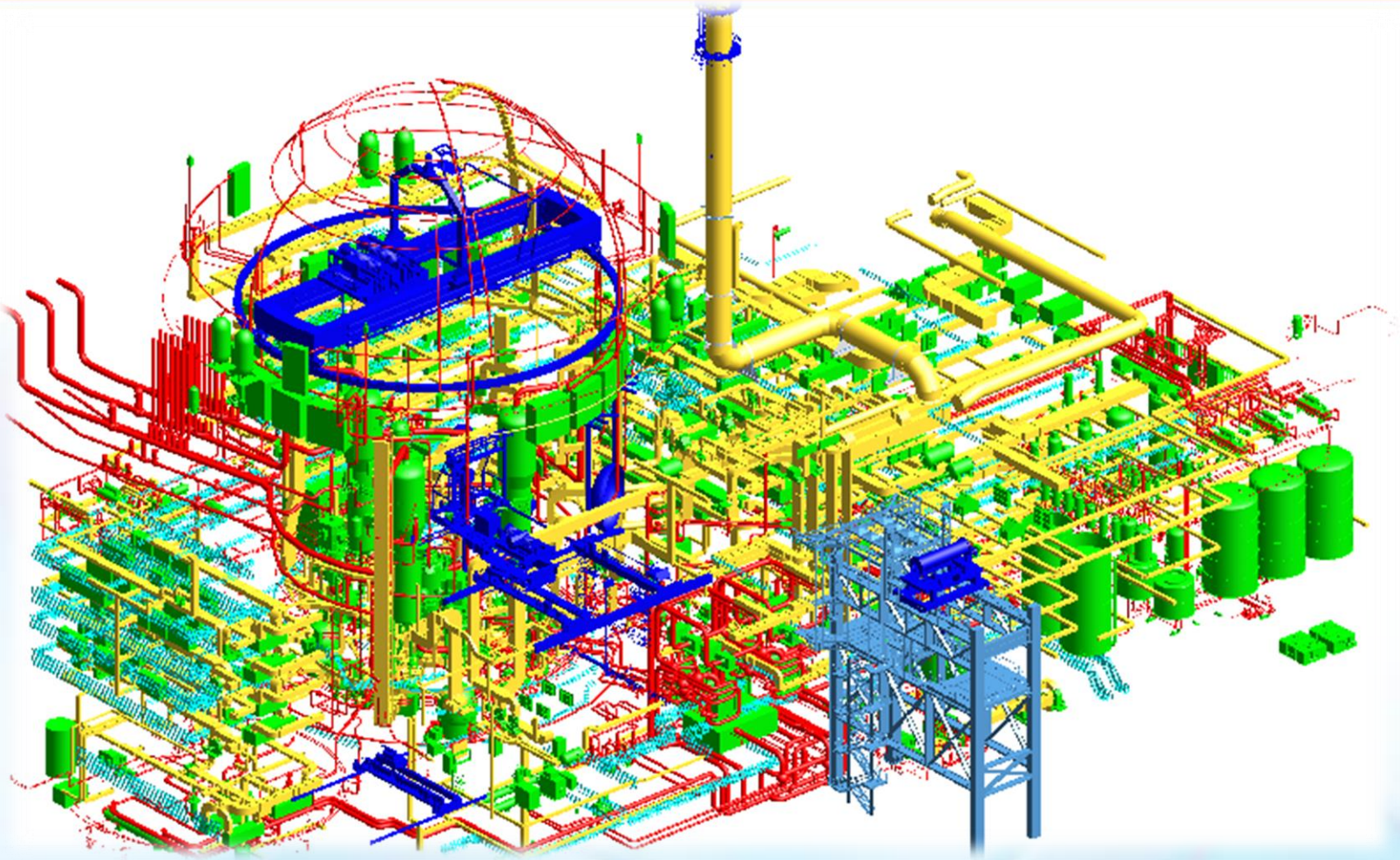
NI: building layout and equipments

4. Engineering Progress



NI: building layout and equipments

4. Engineering Progress



NI: equipments and piping

4. Engineering Progress

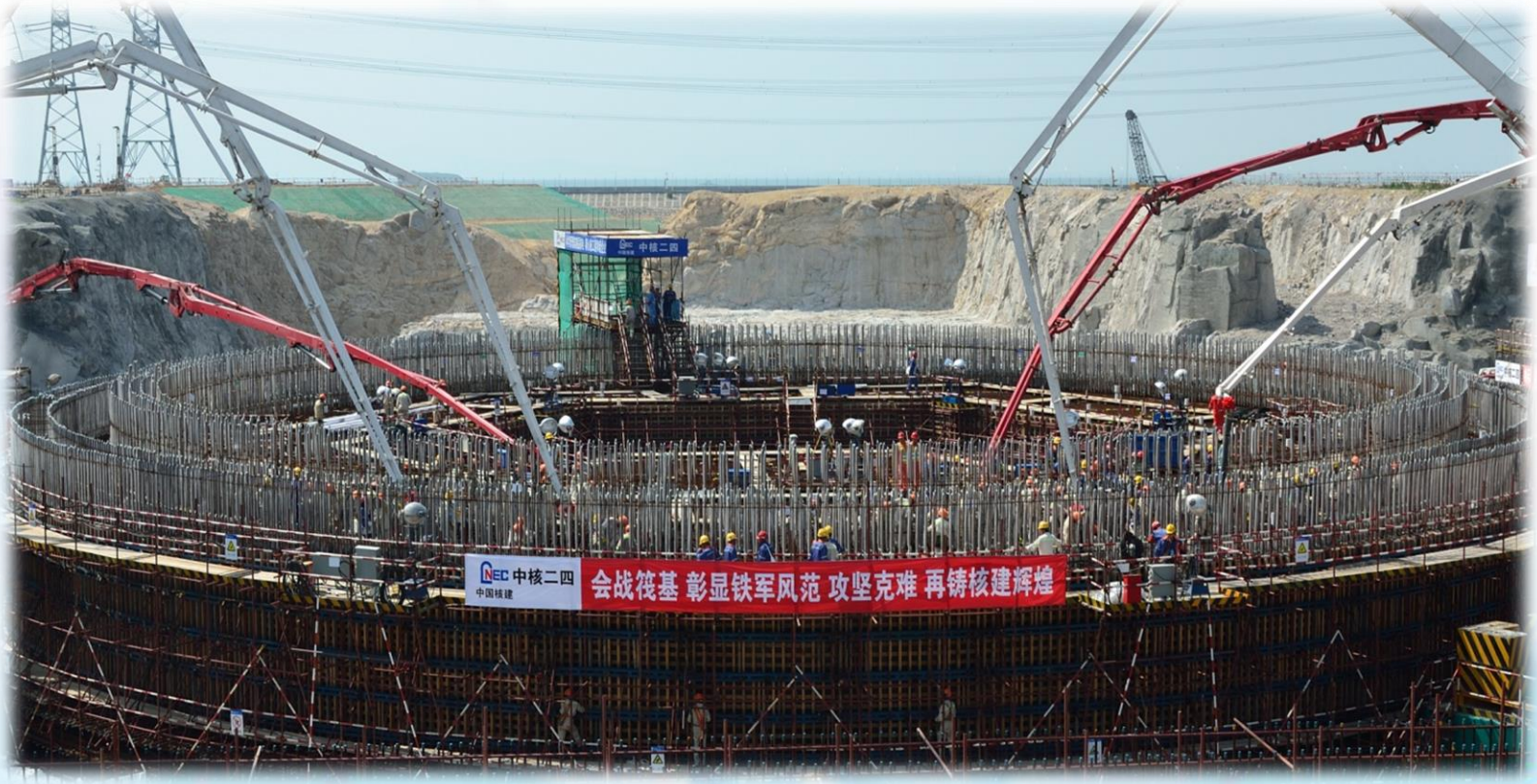
☐ Fuqing NPP Unit 5&6

General Design	Done 2012.9
Basic Design	Done 2013.2
Construction Drawing	On Schedule
Construction Drawing Reservation	+6 months ahead

4. Engineering Progress

☐ Fuqing NPP Unit 5&6

Construction: FCD on May 7, 2015



4. Engineering Progress

☐ Fuqing NPP Unit 5&6

Current Status

5. Summary

Safe

- Active + passive design philosophy
- Increased safety margin
- Digital IC and advanced MCR
- Improved configurations of engineering safety features
- Complete SA prevention & mitigation measures
- Reinforced protection against external hazards
- Improved emergency response capability

Proven

- Normal operation system based on mature technology with rich operation experiences and excellent performances
- Proven equipments and manufacturing capability
- Mature design tools and data base
- Evolutionary technical improvements verified and evaluated by a series of experiments and test

Economic

- Extended refueling cycle of 18 months
- High plant availability ≥ 90%
- Prolonged plant design lifetime of 60 years
- Construction period and cost under control
- Mature equipment procurement channel
- Advanced technology like integrated head assembly , LBB reducing refueling /maintenance cost

5. Summary

- HPR1000 is an advanced PWR which integrated advanced technical features on the basis of proven technology.
- HPR1000 satisfies the latest nuclear safety codes, and meets the utility requirements of Generation III NPP.
- HPR1000 is a safe, clean, economic and reliable global energy solution.

Thanks for your Attention!