OECD/NEA-IAEA Joint Expert Workshop

SMART

For Electricity Generation and Desalination

April 4, 2013

Paris, France

SMART PM

Keung Koo Kim

Advanced Reactor Development

KAERI Korea Atomic Energy Research Institute

Outline

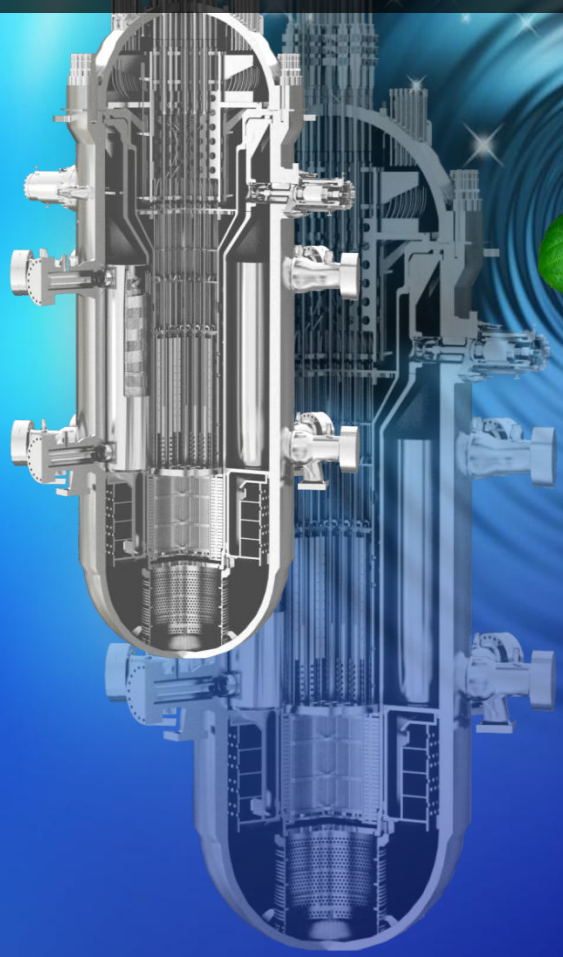
I. SMART for Dual Application

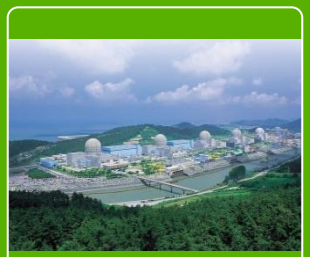
II. SMART Development

III. SMART Characteristics

IV. Summary

I. SMART for Dual Application

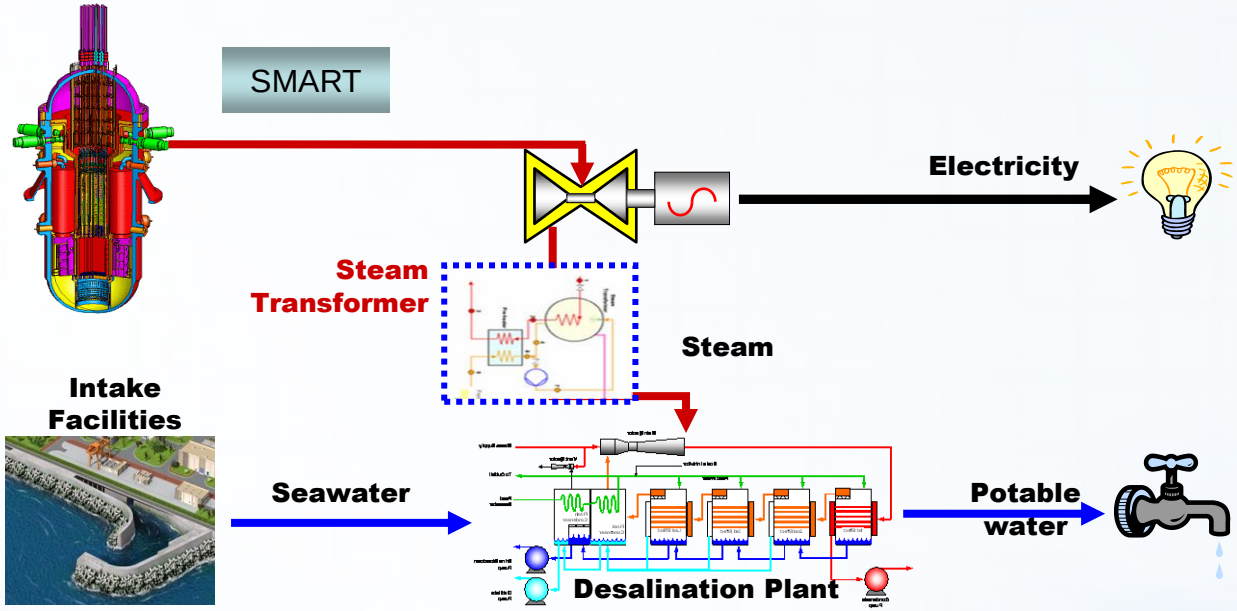




SMART Application

330MW$_{th}$ Integral PWR

Electricity Generation, Desalination and/or District Heating



Plant Data

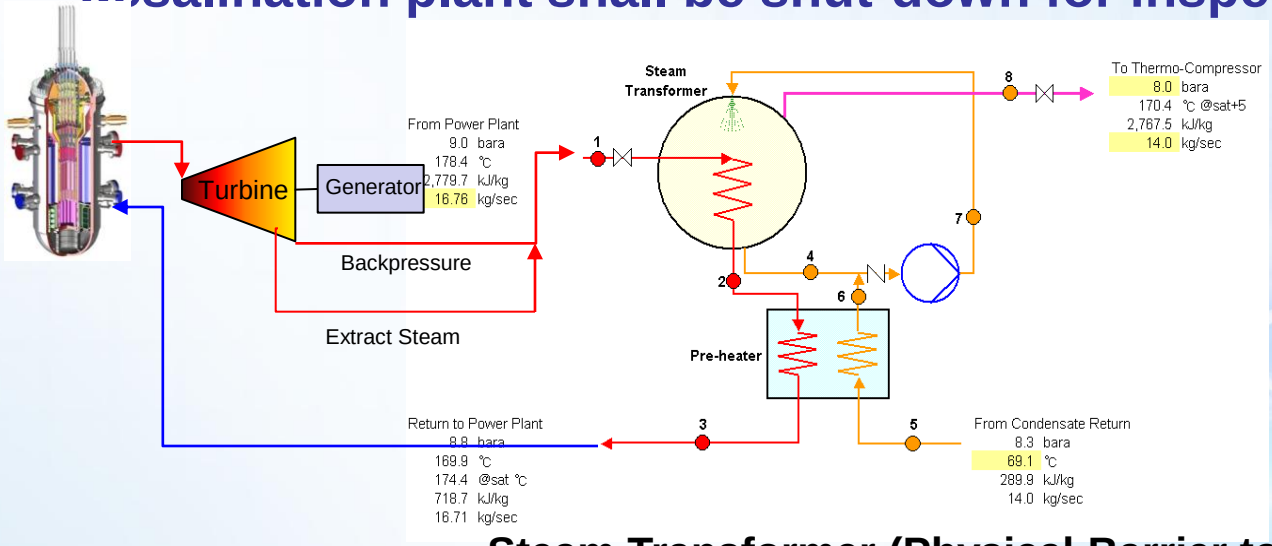
- Power : 330 MWt
- Water : 40,000 t/day
- Electricity: 90 MWe

System-integrated Modular Advanced ReacTor

- ❑ Electricity and Fresh Water Supply for a City of 100,000 Population (Korean)
- ❑ Suitable for Small Grid Size or Localized Power System

Safety Requirements for Desalination

- Any form of radioactive particles shall not be transferred to the distillate
  - Suitable means shall be considered to do
- Radioactivity in main steam line shall be monitored on real time
  - When radioactive material is detected in main steam line, desalination plant shall be shut-down for inspection.



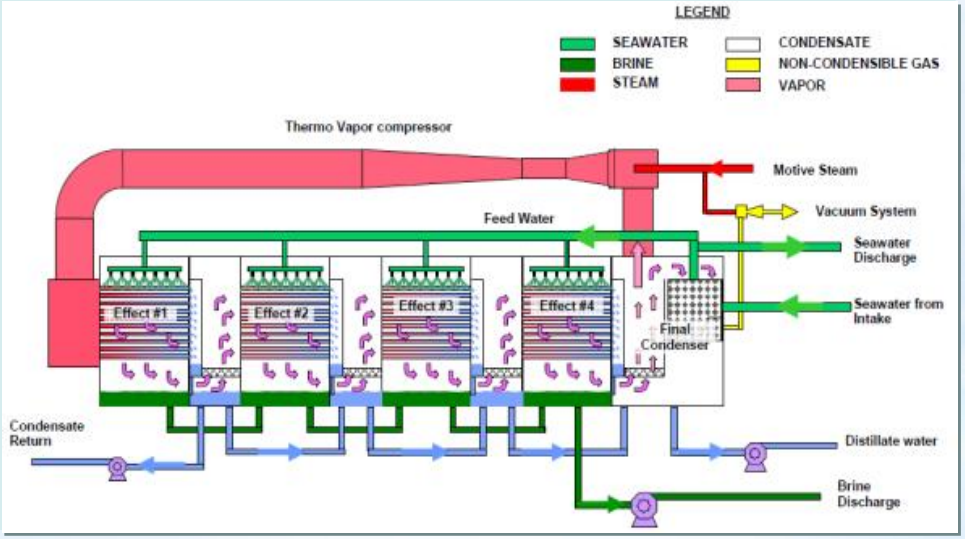
Steam Transformer (Physical Barrier to prevent Radioactive material Transfer)

SMART Desalination System

MED Desalination

- 40,000 ton/day + 90 MWe (Optimal)
  - 4 Units of MED-TVC (10 Effects)
  - Steam Extract from Turbine
- 77,000 ton/day + 83 MWe
  - Back Pressure Turbine

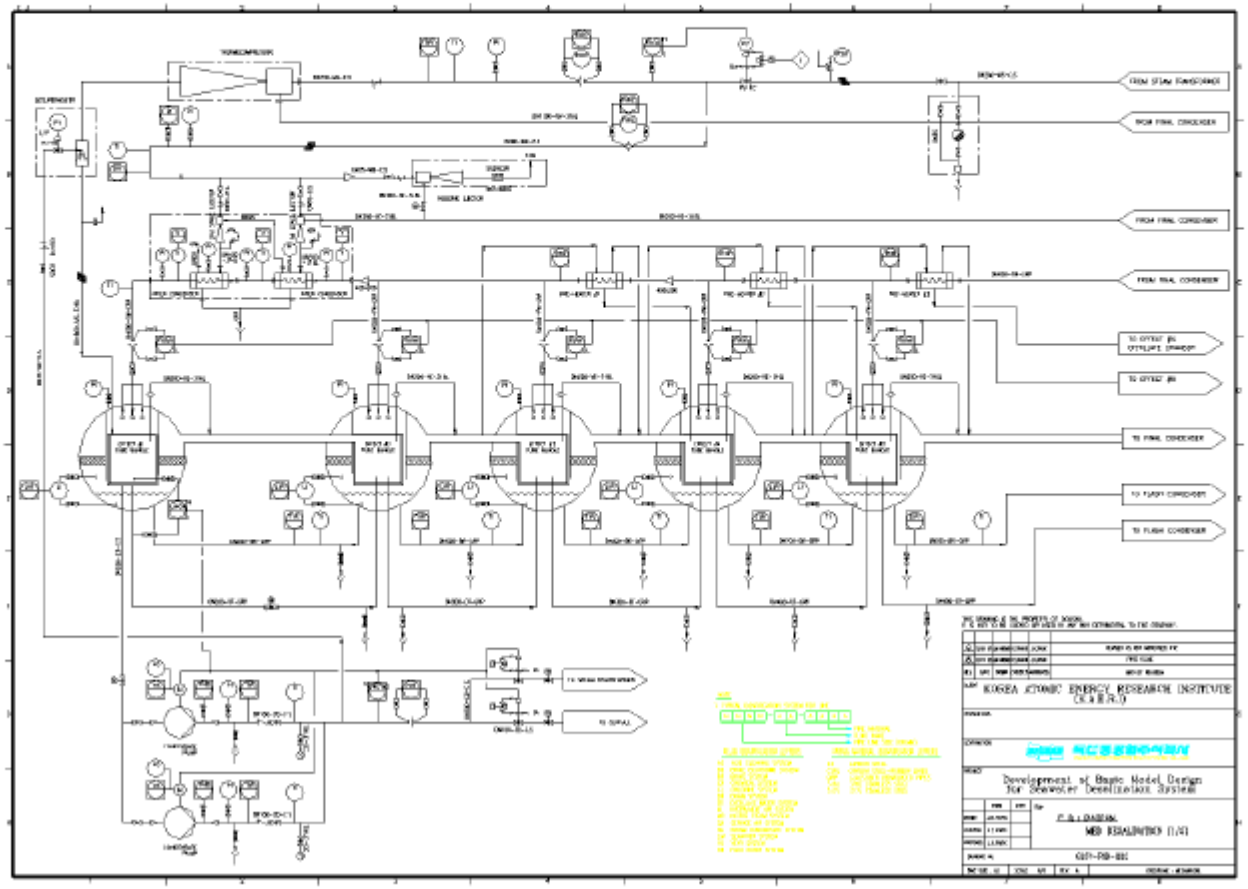
MED Desalination Plant



Schematic Diagram of MED-TVC

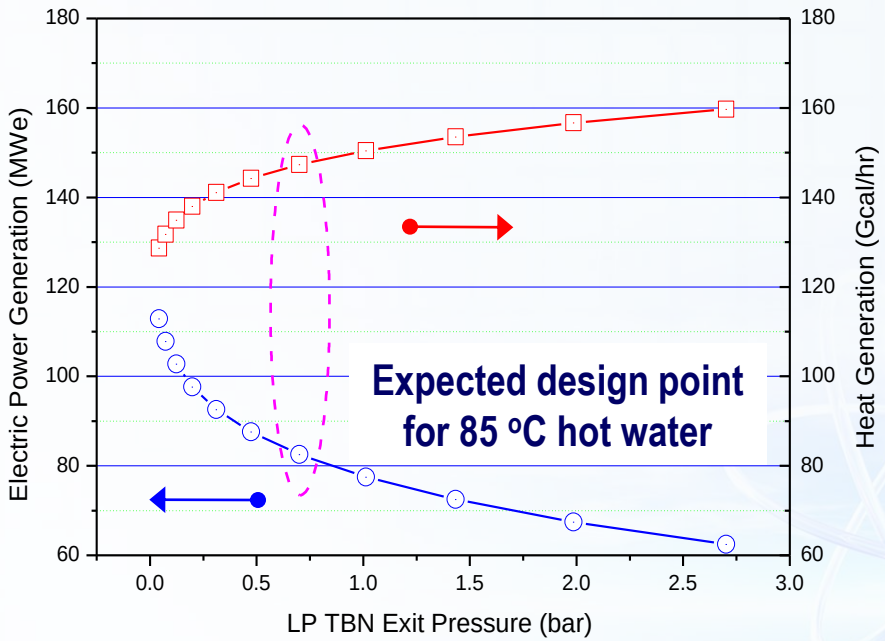
DOOSAN Heavy Industries & Construction

Process Flow Diagrams

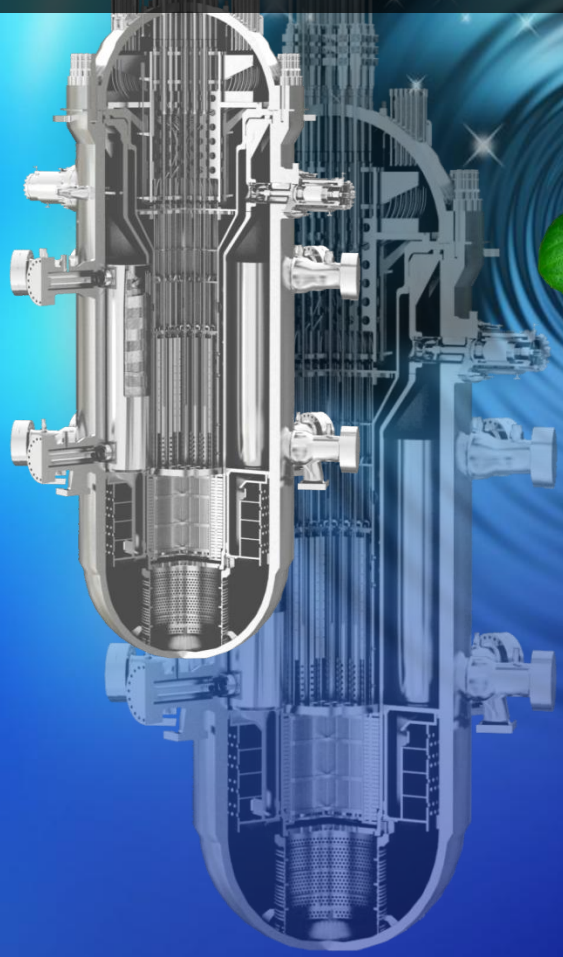


District Heating

- 147 Gcal/h of Heat Supply to Local Area Heating + 82 MWe
- Supply of Electricity and 85°C Hot Water for 100,000 Populations
  - Based on Korean Peak Electric Power and Heat Usages



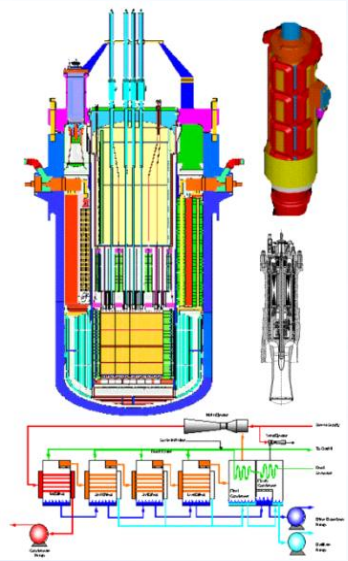
II. SMART Development

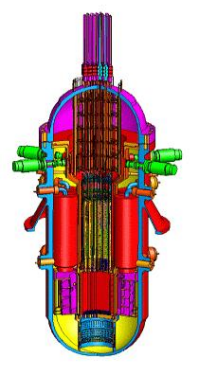


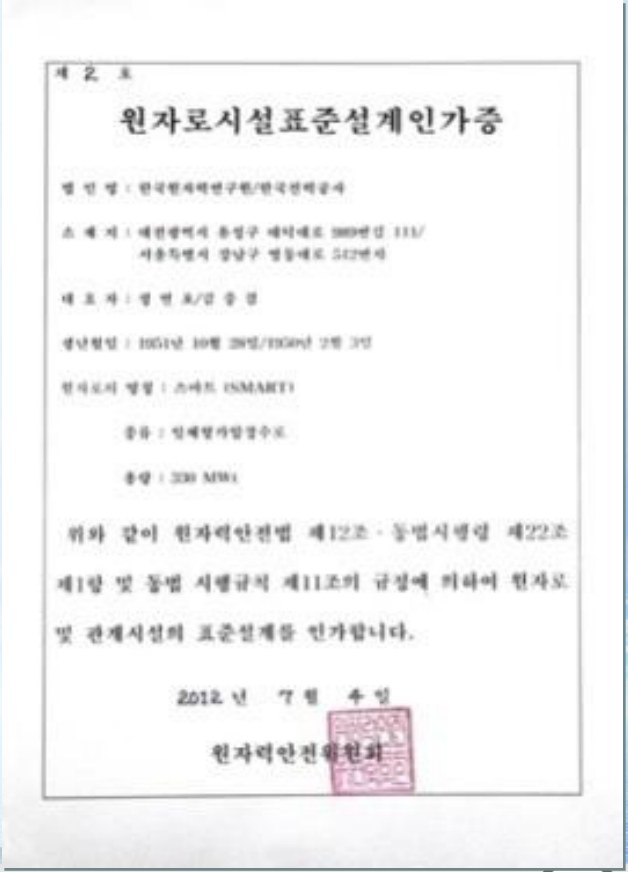
Development History

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014

Conceptual Design	Basic Design	SMART-P (65MWt) Development	Pre Project	Design Optimization	SMART Standard Design Approval	Domestic Const. & Export







제 2 호

원자로시설표준설계인가증

성 명 : 한국원자력연구원/한국전력공사

소 재 지 : 대전광역시 유성구 대덕대로 989번길 111/
서울특별시 강남구 영동대로 512번지

대 표 자 : 성 명 표/김 중 경

생년월일 : 1951년 10월 28일/1950년 2월 3일

원자로의 명칭 : 스마트 (SMART)

종류 : 일체형가압경수로

출력 : 330 MWt

위와 같이 원자력안전법 제12조 · 동법시행령 제22조 제1항 및 동법 시행규칙 제11조의 규정에 의하여 원자로 및 관계시설의 표준설계를 인가합니다.

2012 년 7 월 수 일

원자력안전위원회

Total 1500MY and ~300M$ are invested

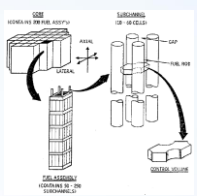
SMART Development

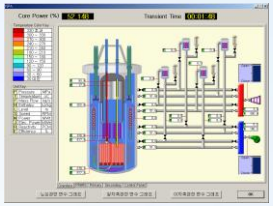
Methodology

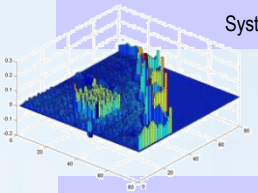
Reactor Design Methodology

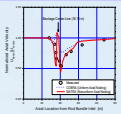
Topical Report for Licensing Approval

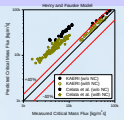
System Design and Analysis Methodology, Fuel Design Technology











Computer Program Development

Improvement/ Applicability Evaluation

Verification

Design & Licensing

SSAR, CDM, ITAAC, etc

SMART-330
NSSS Basic Design

0 design & Li

SMART Basic Design

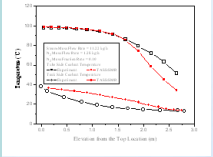
Standard Design

License

SDA

Constructio
n

Validation Tests



Separate Effect Tests
MMIS Essential Tech. Verification Tests
Small Scale Hi Temp. & Pres. Tests

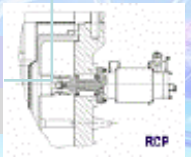
Separate Effect Tests for Transients
Digital Safety System Verification Tests
Integral T/H Verification Tests

Hardware

S/G, RCP, CRDM, etc.

Mockup Tests

S/G, RCP, CRDM, etc.



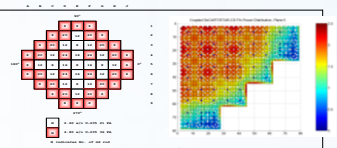
Small Scale Component Tests

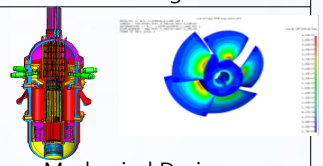
Fuel Development & Test

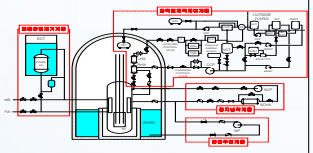
Standard Design

KAERI | KEPCO NF | DOOSAN 두산중공업 | KEPCO E&C

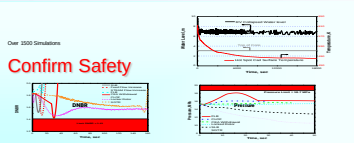
NSSS Design


Core Design


Mechanical Design

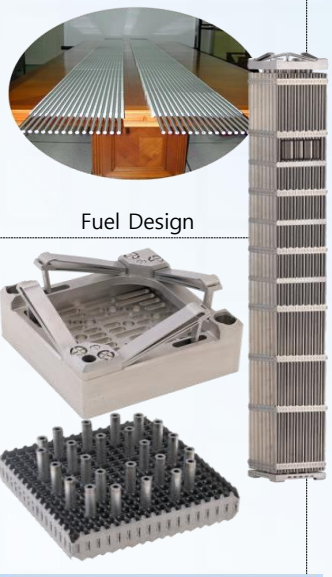

System Design

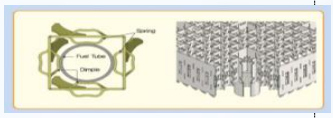

MMIS Design

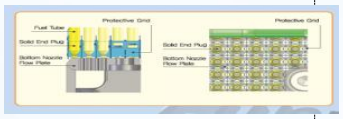


Safety Analysis

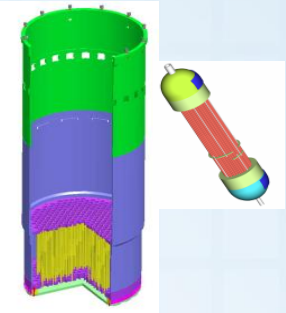
Fuel Design

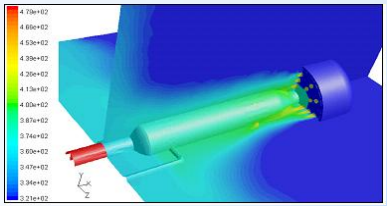

Fuel Design




Fuel Assembly Design

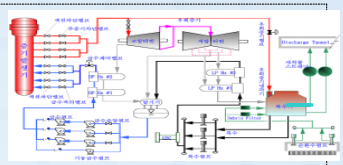
Component Design


Component Design


Component Design Analysis

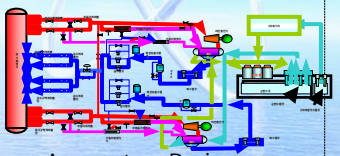

Equipment Vendor Survey

BOP/AE Design

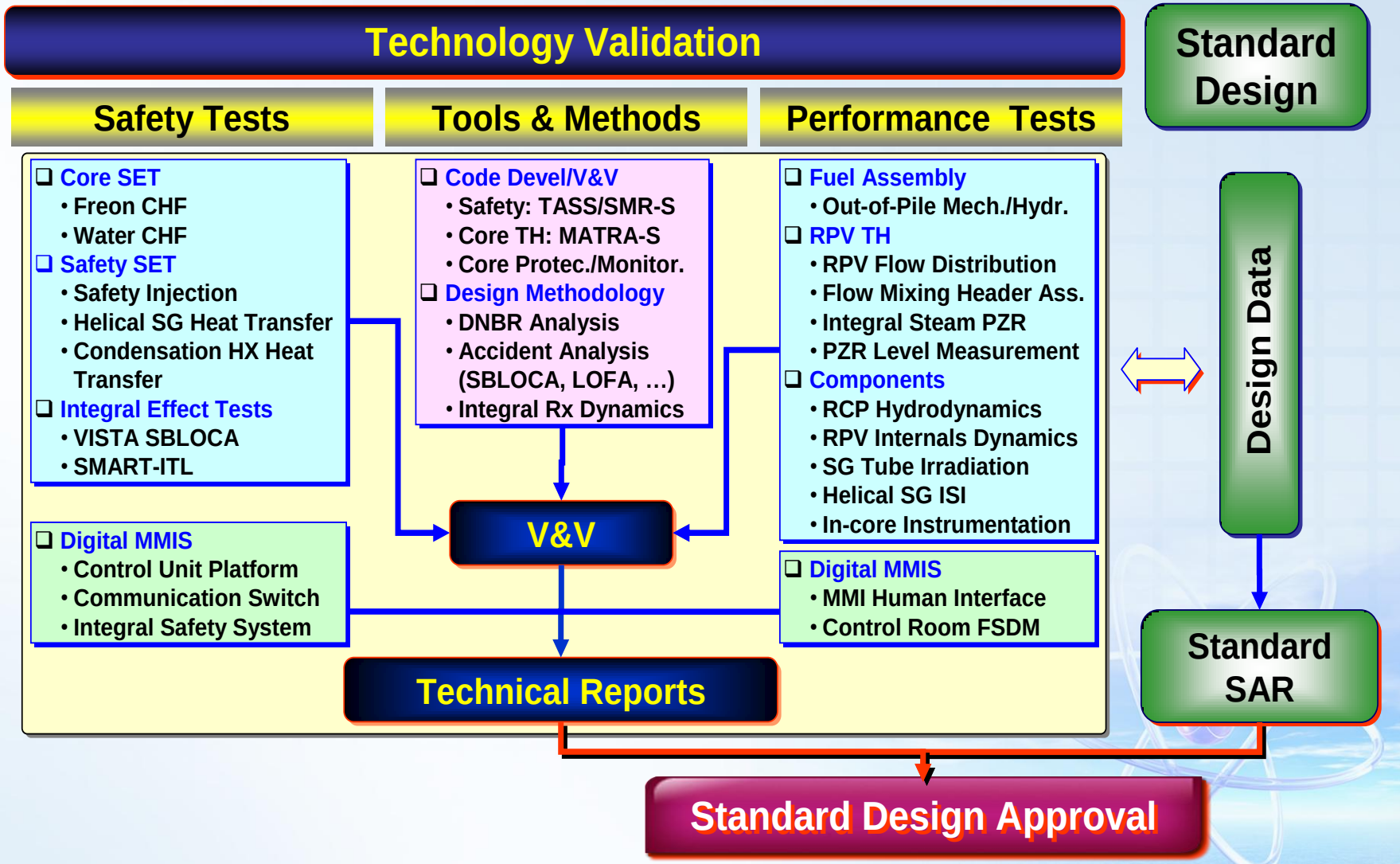

Main Feedwater and Main Steam


General Arrangement


Containment Building


Aux. system Design

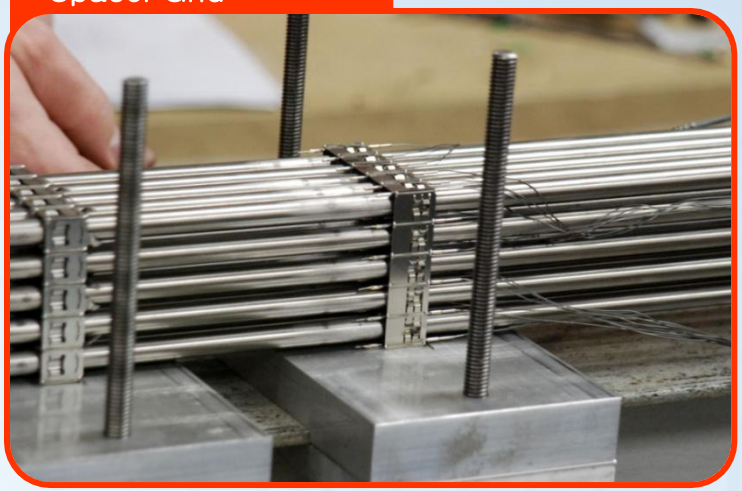
Technology Validation



Core & Fuel

TEST Fuel

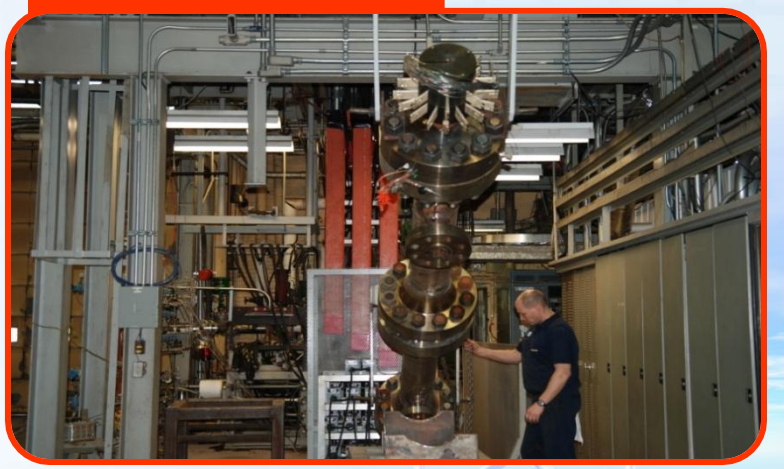
Spacer Grid



Measurement

TEST Section

TEST Section



Fuel Performance Tests

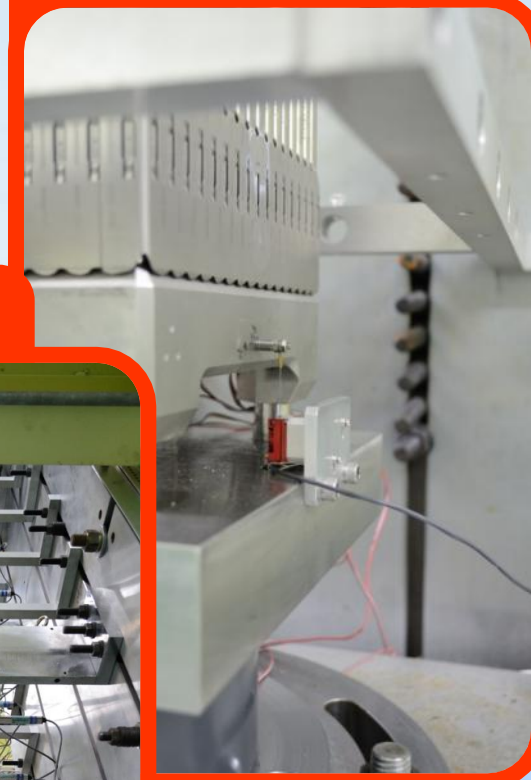
CHF Measurement Test

Fuel Mechanical Performance Test

Vibration TEST

Bending TEST

Impact TEST



Mechanics and Components

Dynamic Test

RCP TEST Loop

Low Friction Cable

RPV Dynamics Tests, RCP Mockup Test and Helical ISI Test

TEST Facility

SG Tube Material (A690) Irradiation Test

Thermal-Hydraulics Experiment

PRHRS Heat Ex.

Pressurizer

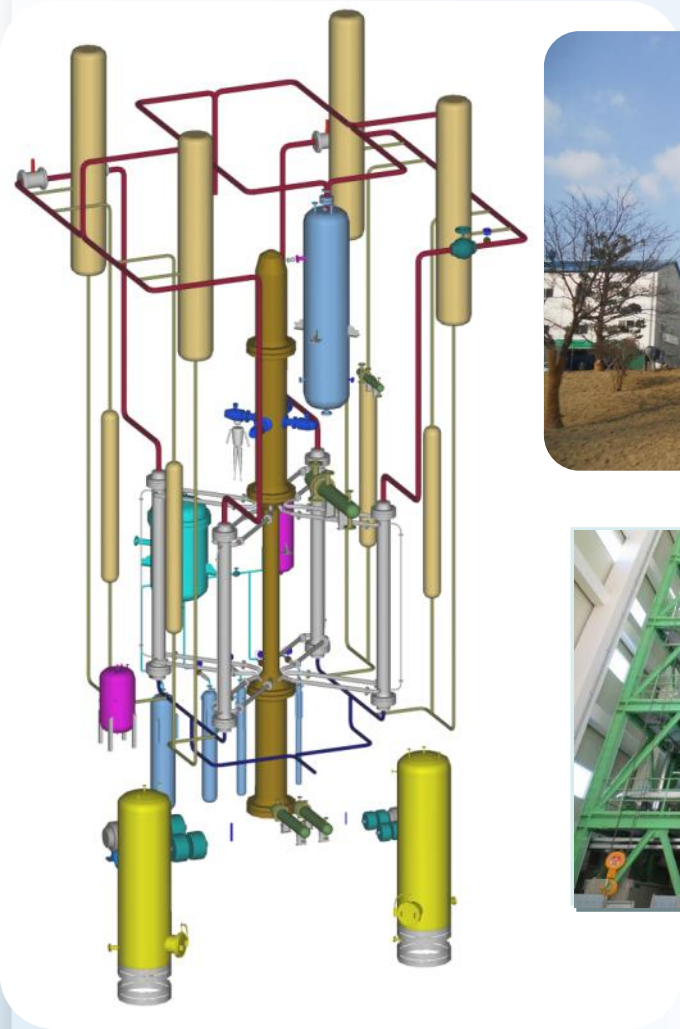
Safety Injection

VISTA

Thermal-Hydraulic Performance Tests

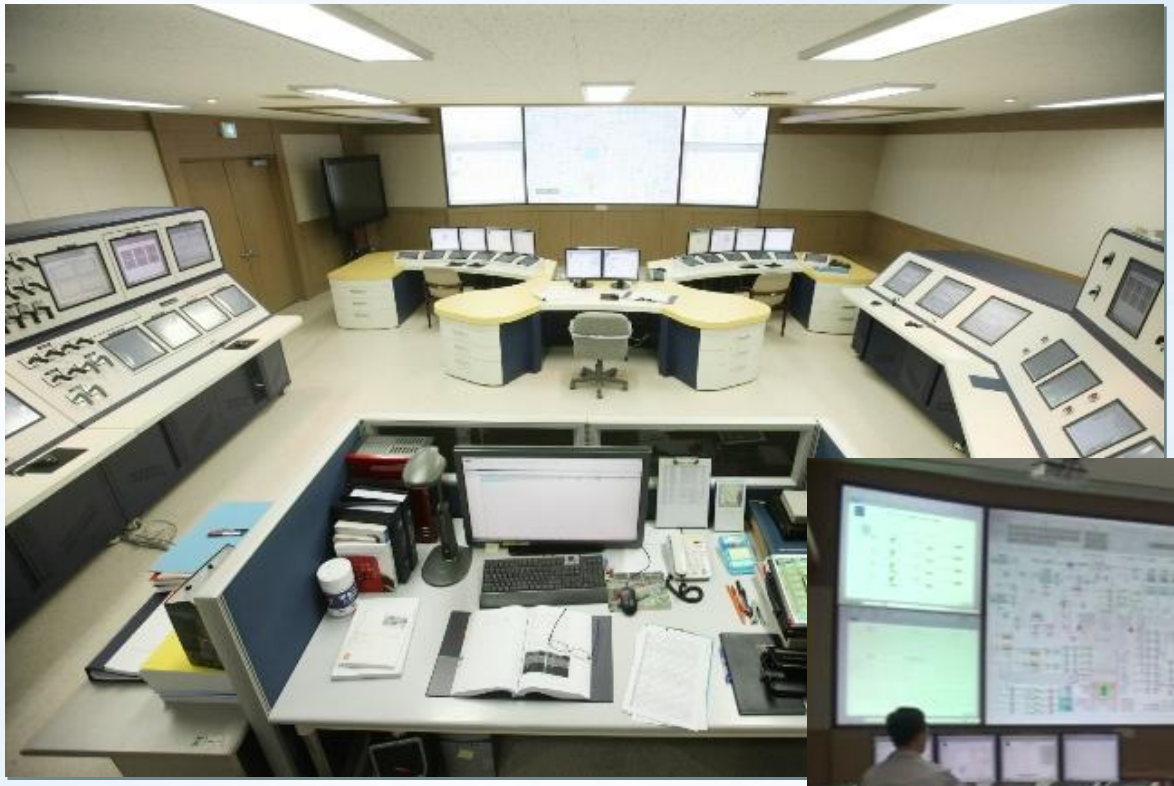
SMART ITL(Integral Test Loop)

- World's Unique and Largest Full Scope Accident Simulation
  - 1:1 Height, 1/49 Volume



Man-Machine Interface System

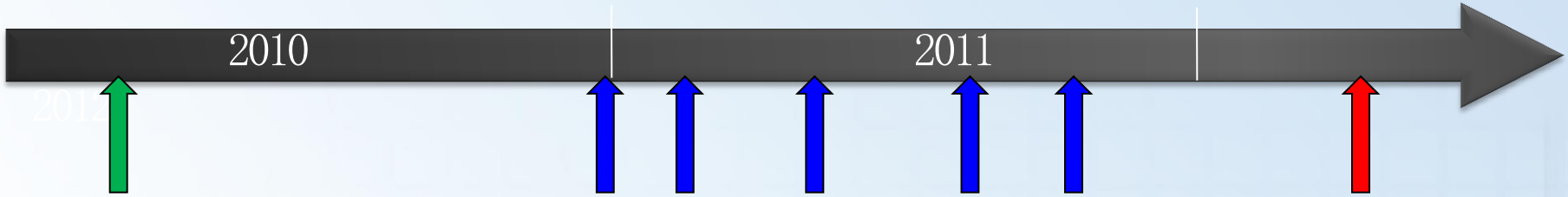
- **Digital Main Control Room Validation**
  - **FSDM (Full-scope Dynamic Mockup)**



Real Operators in FSDM

* It's Real Photo, not Graphics

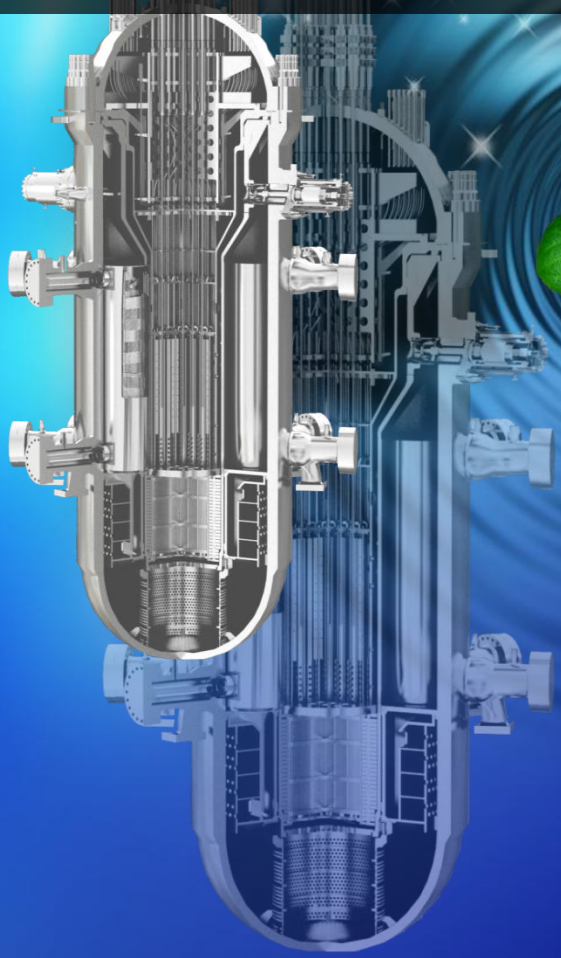
Licensing



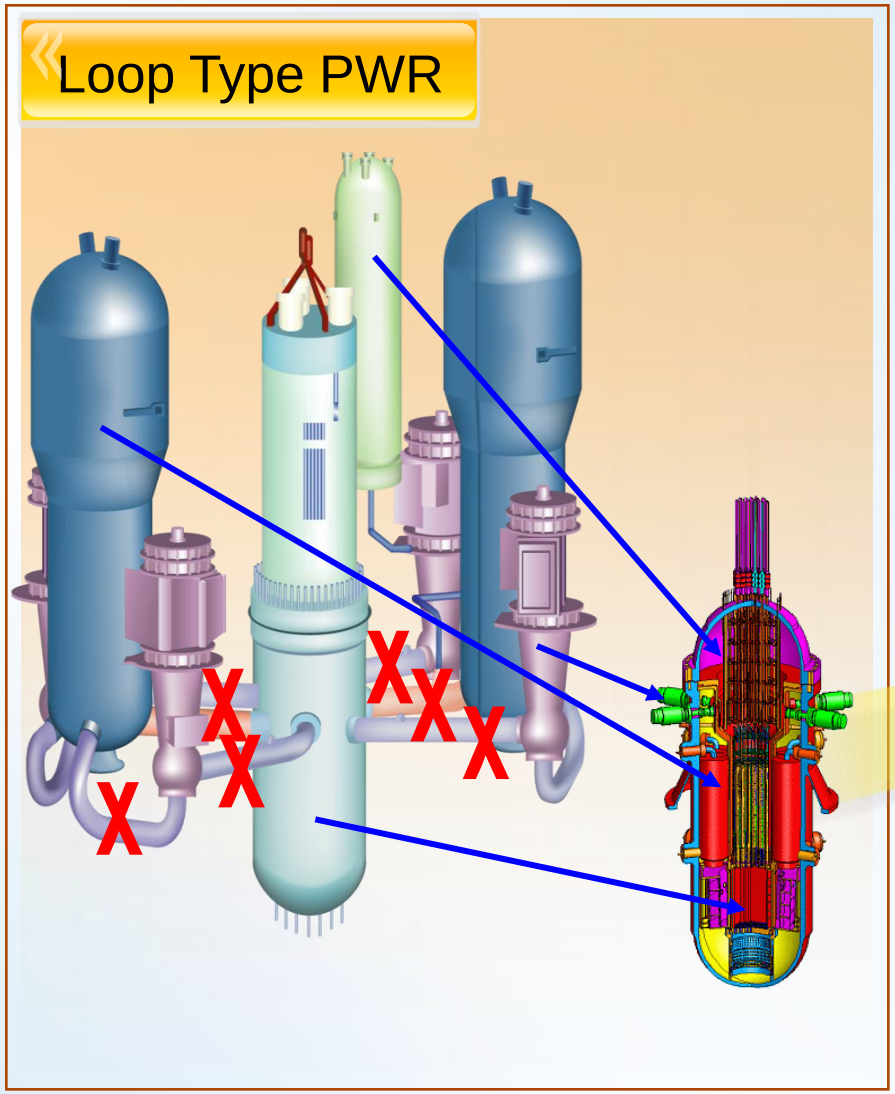
- **Pre-application Review by KINS (Feb. 2010)**
- **Application of Standard Design Approval (Dec. 30, 2010)**
  CDM, SSAR, EOG and related documents
- **Document Conformance Evaluation (~Feb. 2011)**

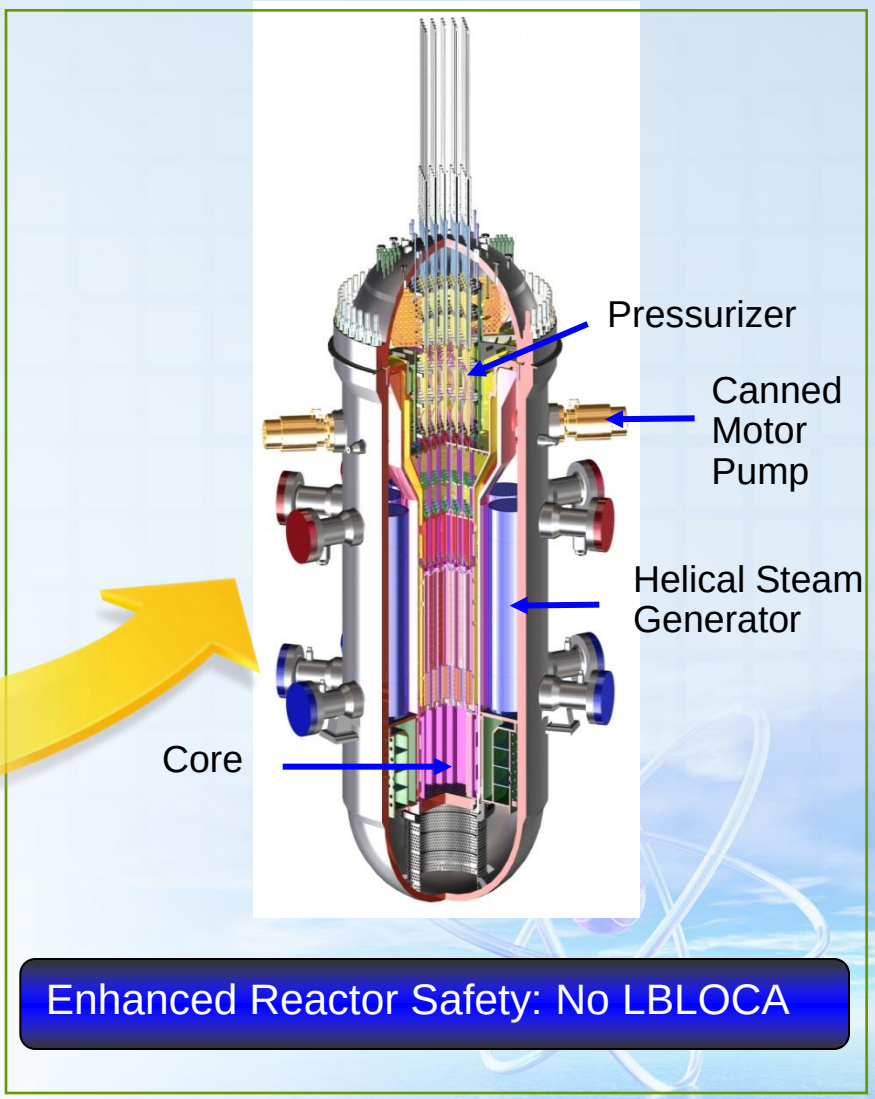
- **1st Round Questionnaire : April 30, 2011**
- **2nd Round Questionnaire : July 31, 2011**
- **3rd Round Questionnaire : October, 2011**
- **4th Round Questionnaire : December, 2011**
- **Additional Questionnaire: January ~ April, 2012**
- **Standard Design Approval : July 4, 2012**

III. SMART Characteristics



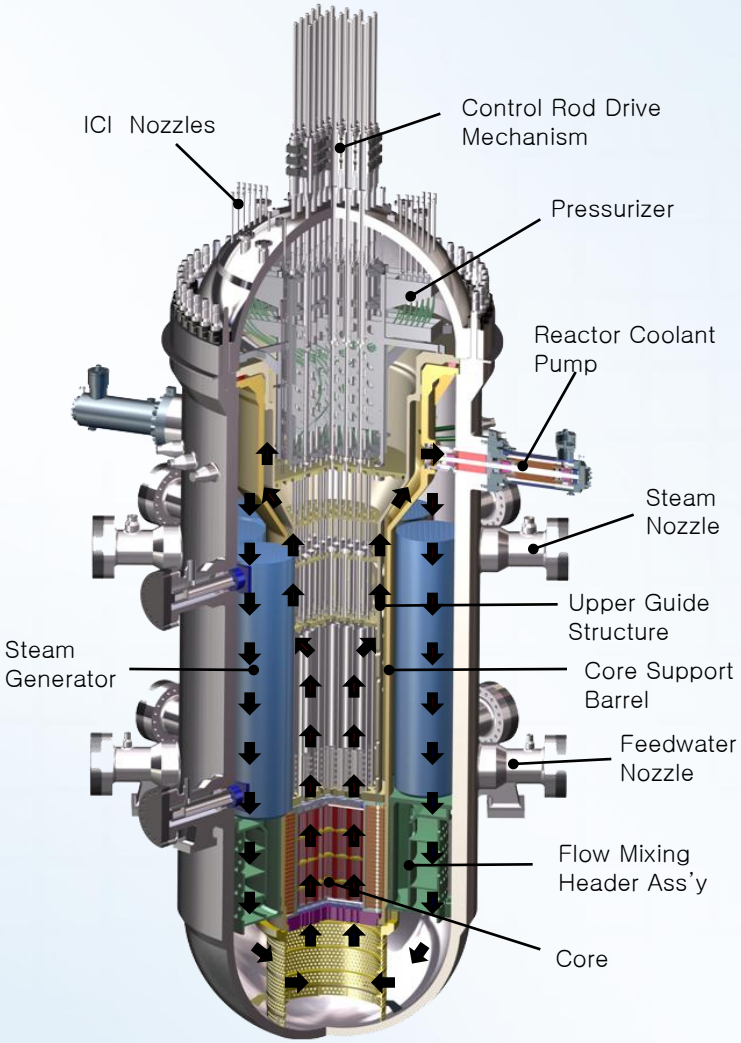
Integral Reactor





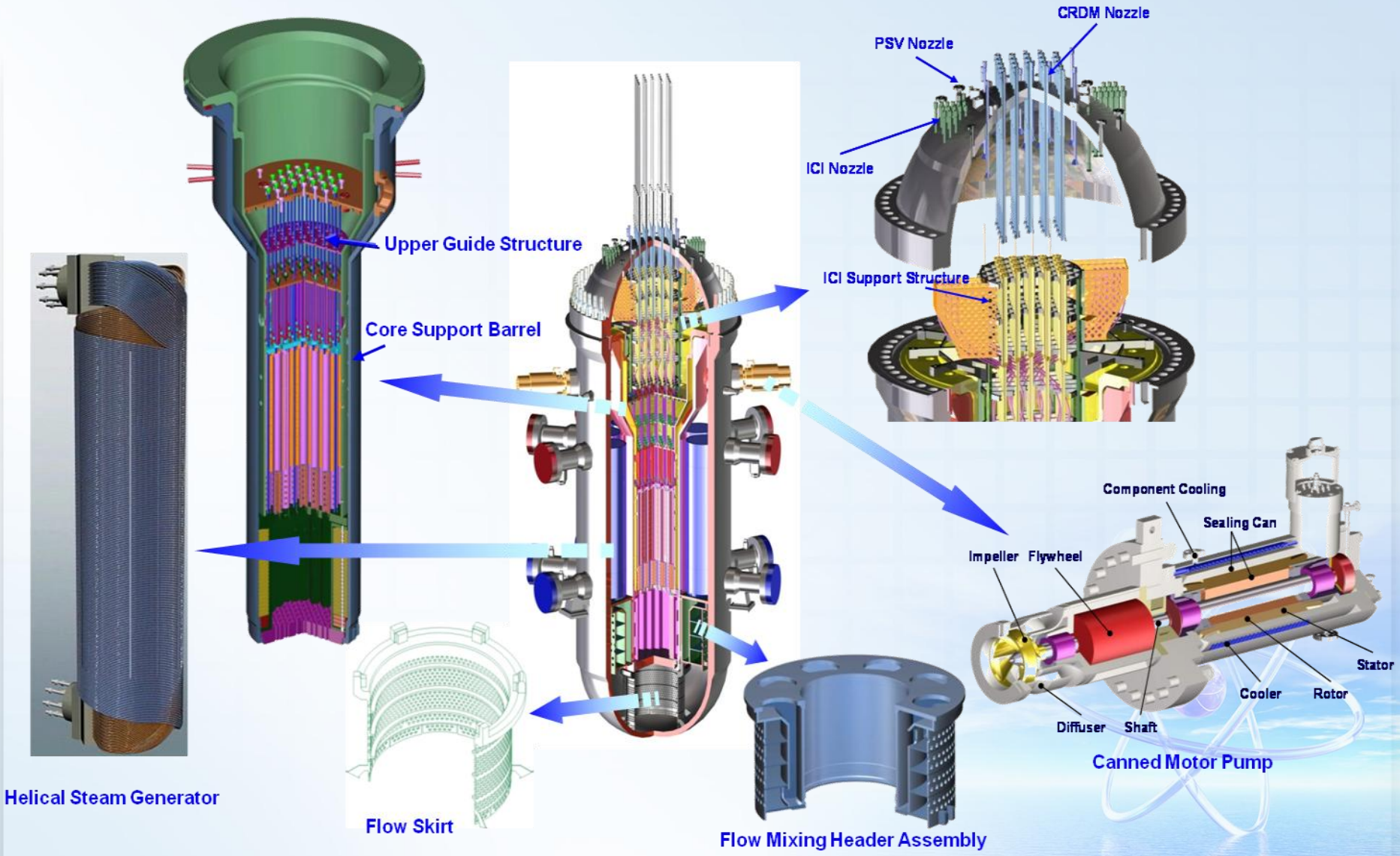
Enhanced Reactor Safety: No LBLOCA

Reactor Vessel Assembly



- ❑ **No large RPV penetrations**
  - Less than 2 inch penetrations
- ❑ **In-Vessel Steam Pressurizer**
- ❑ **8 Helical Steam Generators**
  - Once through SG
  - Produce superheated steam
- ❑ **4 Reactor Coolant Pumps**
  - Canned motor type
  - Horizontally mounting
- ❑ **57 Fuel Assemblies**
  - Standard 17x17 UO_2 (< 5 w/o U^{235}) w/ reduced height (2m)
  - Performance proved at operating PWRs

RPV - Internals



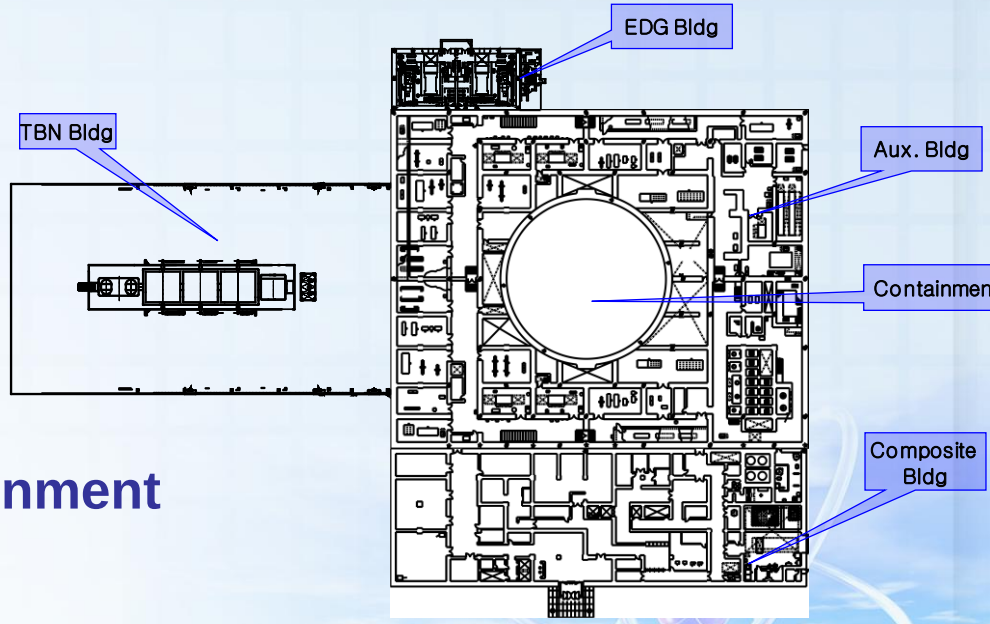
Balance of Plant

❑ Containment Building

- Hydrogen Recombiner: 12 Passive Autocatalytic Recombiners
- Containment Spray System (2 Train)
- Containment Isolation System
- Aircraft Impact Proof

❑ Auxiliary Building

- Quadrant Wrap-around
- Fuel Building Inside
- Aircraft Impact Proof
- Single Basemat with Containment (Seismically Resistant)



General Arrangement

Single Unit Construction

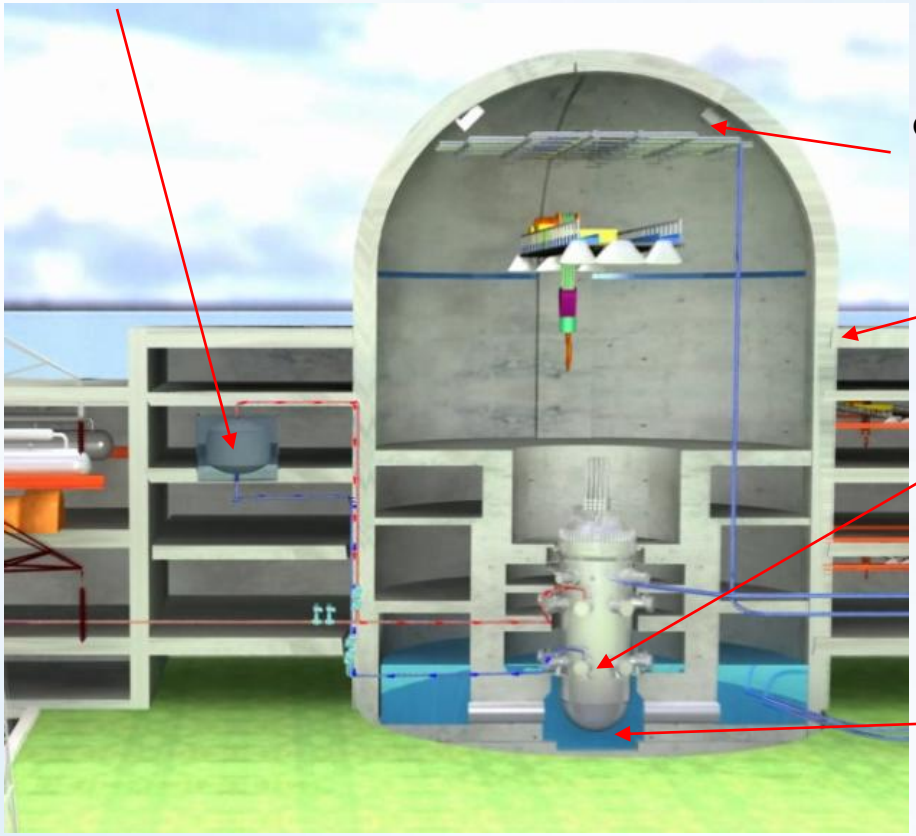
300 x 300m for Power System

Twin Units Construction

~20% More Economical than Single Unit

Enhanced Safety

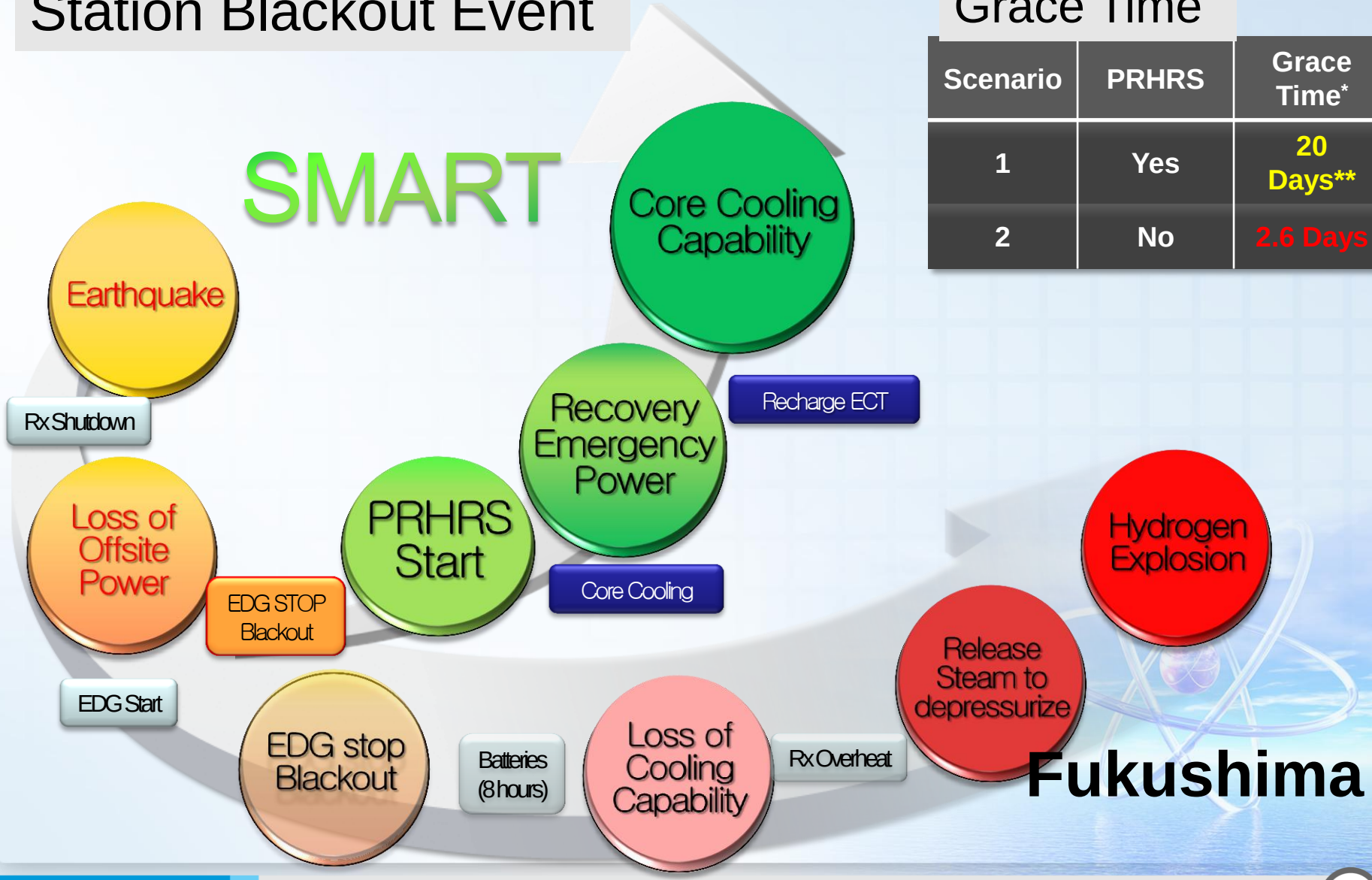
- **Passive Residual Heat Removal system**
  - 20 days grace period against Fukushima-type accident



- **Passive Hydrogen Removal System**
  - Prevent Hydrogen Explosion
- **Containment Building**
  - Air craft (Boeing767) Crash Proof
  - Low Hydrogen Concentration
- **Minimize Fuel Failure**
  - Fuel submerged during all DBA
- **Passive Ex-Vessel Cooling**
  - Prevent Vessel Failure

SMART vs. Fukushima

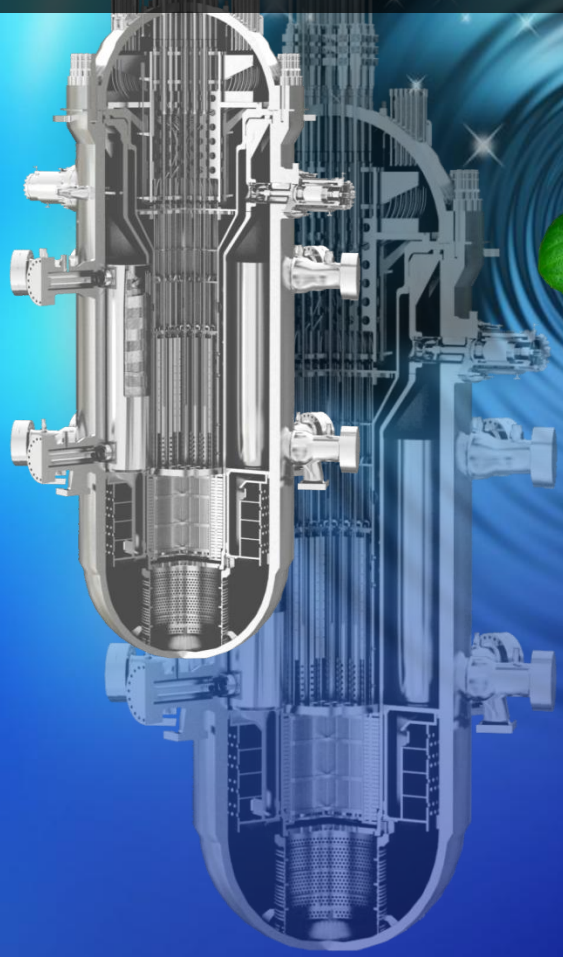
Station Blackout Event



Grace Time

Scenario	PRHRS	Grace Time*
1	Yes	20 Days**
2	No	2.6 Days

IV. Summary



Summary

- Multiple Application
  - Electricity generation, seawater desalination, district heating and process heat to industries
- Safe in Fukushima Accident Condition
  - The core is maintained undamaged for up to 20 days without any corrective actions by the operator
- First to the Market
  - The standard design of SMART and Technology Validation was completed
  - Standard design approval was granted on July 4, 2012

Thank You !!

KAERI

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