I. SMART for Dual Application
SMART Application

330MWth 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)
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

http://www.kaeri.re.kr
Desalination Design

Process Flow Diagrams

SMART System Integrated Modular Advanced Reactor
- 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

**Expected design point for 85°C hot water**
II. SMART Development
Total 1500MY and ~300M$ are invested
SMART Development

Methodology

- Reactor Design Methodology
- Computer Program Development

Design & Licensing

- SMART-330
  - NSSS Basic Design
- SMART Basic Design

Validation Tests

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

Hardware

- Small Scale Component Tests

SDA

Verification

- Topical Report for Licensing Approval

Computer Program Development

- Improvement/ Applicability Evaluation

SSAR, CDM, ITAAC, etc.

Standard Design

License

Verify

Hardware Validation Tests

- System Design and Analysis Methodology, Fuel Design Technology

Mockup Tests

- S/G, RCP, CRDM, etc.

Fuel Development & Test

More than 4,000 design & Licensing Documents

Improvement/ Applicability Evaluation

http://www.kaeri.re.kr
Standard Design

NSSS Design

Fuel Design

Component Design

BOP/AE Design

Core Design

Mechanical Design

System Design

MMIS Design

Safety Analysis

Fuel Assembly Design

Component Design Analysis

Equipment Vendor Survey

Main Feedwater and Main Steam

General Arrangement

Containment Building

Aux. system Design

Core Design

Mechanical Design

System Design

MMIS Design

Safety Analysis

Fuel Assembly Design

Component Design Analysis

Equipment Vendor Survey

Main Feedwater and Main Steam

General Arrangement

Containment Building

Aux. system Design

Content includes:
- NSSS Design
- Fuel Design
- Component Design
- BOP/AE Design

Key components:
- Core Design
- Mechanical Design
- System Design
- MMIS Design
- Safety Analysis
- Fuel Assembly Design
- Component Design Analysis
- Equipment Vendor Survey

Notable features:
- Confirmation of safety
- Over 1500 simulations

Additional information:
- SMART System Integrated Modular Advanced Reactor
- KAERI
- ICEPCo
- Doosan
- Equipment Vendor Survey
- General Arrangement
- Containment Building
- Aux. system Design
Technology Validation

Safety Tests
- Core SET
  - Freon CHF
  - Water CHF
- Safety SET
  - Safety Injection
  - Helical SG Heat Transfer
  - Condensation HX Heat Transfer
- Integral Effect Tests
  - VISTA SBLOCA
  - SMART-ITL

Tools & Methods
- Code Devel/V&V
  - Safety: TASS/SMR-S
  - Core TH: MATRA-S
  - Core Protec./Monitor.
- Design Methodology
  - DNBR Analysis
  - Accident Analysis (SBLOCA, LOFA, ...)
  - Integral Rx Dynamics

Performance Tests
- Fuel Assembly
  - Out-of-Pile Mech./Hydr.
- RPV TH
  - RPV Flow Distribution
  - Flow Mixing Header Ass.
  - Integral Steam PZR
  - PZR Level Measurement
- Components
  - RCP Hydrodynamics
  - RPV Internals Dynamics
  - SG Tube Irradiation
  - Helical SG ISI
  - In-core Instrumentation

Digital MMIS
- Control Unit Platform
- Communication Switch
- Integral Safety System

Technical Reports
- Digital MMIS
  - MMI Human Interface
  - Control Room FSDM

V&V

Standard Design Approval

Standard Design

Design Data

Standard SAR
Fuel Performance Tests

CHF Measurement Test
Fuel Mechanical Performance Test

- Impact TEST
- Vibration TEST
- Bending TEST
Mechanics and Components

- Dynamic Test
- RCP TEST Loop
- TEST Facility
- Low Friction Cable
- RPV Dynamics Tests, RCP Mockup Test and Helical ISI Test
- SG Tube Material (A690) Irradiation Test
Thermal-Hydraulic Performance Tests
SMART ITL (Integral Test Loop)

World’s Unique and Largest Full Scope Accident Simulation
- 1:1 Height, 1/49 Volume
Digital Main Control Room Validation
- FSDM (Full-scope Dynamic Mockup)

* It’s Real Photo, not Graphics

Real Operators in FSDM
• 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)
• 1\textsuperscript{st} Round Questionnaire : April 30, 2011
• 2\textsuperscript{nd} Round Questionnaire : July 31, 2011
• 3\textsuperscript{rd} Round Questionnaire : October, 2011
• 4\textsuperscript{th} Round Questionnaire : December, 2011
• Additional Questionnaire: January ~ April, 2012
• Standard Design Approval : July 4, 2012
III. SMART Characteristics
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 UO₂ (< 5 w/o U²³⁵) w/ reduced height (2m)
- Performance proved at operating PWRs
RPV - Internals

- Upper Guide Structure
- Core Support Barrel
- Flow Skirt
- Flow Mixing Header Assembly
- Helical Steam Generator
- Canned Motor Pump
- CRDM Nozzle
- PSV Nozzle
- ICI Nozzle
- ICI Support Structure

Component Cooling
Impeller Flywheel
Sealing Can
Cooler Rotor
Diffuser Shaft
Stator
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**

**SMART**

1. Earthquake
2. Loss of Offsite Power
3. Rx Shutdown
4. PRHRS Start
5. EDG STOP Blackout
6. EDG Start
7. EDG Stop Blackout
8. Batteries (8 hours)
9. Loss of Cooling Capability
10. Rx Overheat

**Core Cooling Capability**

**Recovery Emergency Power**

**Recharge ECT**

**Fukushima**

- **Hydrogen Explosion**
- **Release Steam to depressurize**

**Grace Time**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PRHRS</th>
<th>Grace Time*</th>
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<tbody>
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<td>20 Days**</td>
</tr>
<tr>
<td>2</td>
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<td>2.6 Days</td>
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*Grace Time calculated from the time of station blackout event

**Station Blackout Event Scenarios**

1. **EDG Stop**
2. **Rx Overheat**
IV. 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 !!