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Nuclear Safety Research in Korea in Light of Fukushima Accident

Presentation in Session
"International Research – Post-Fukushima Research"
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Outline

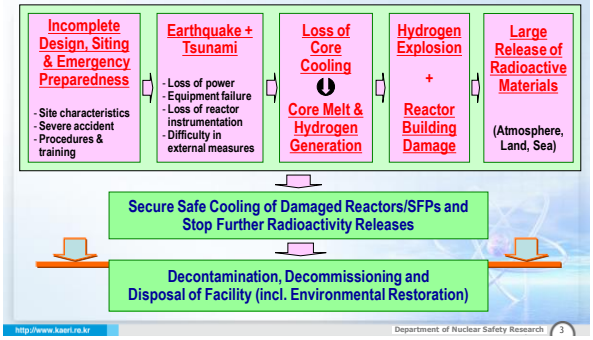
- Nuclear Energy in Korea
- Fukushima Accident
- Nuclear Safety Research (NSR) in Korea
- KAERI's NSR after Fukushima Accident
- Concluding Remarks

Nuclear Energy in Korea

- Overview
  - 23 operable nuclear power reactors
    - 19 PWRs and 4 PHWR-CANDUs
    - Installed capacity of 20.7 GWe
    - 30~35% share of country's electricity supply
  - 5 PWR units under construction
    - 1 OPR1000's and 4 APR1400's
  - 4 additional APR1400 units by 2021 (planned)
  - The most economical source of electricity in Korea
  - Longer-term role of nuclear energy under debate

Fukushima Accident (1)

❑ Overall Progression of the Accident



Fukushima Accident (2)

❑ Key Characteristics of the Accident

- **Severe Accident Initiated by an Extreme Natural Disaster**
  - TMI & Chernobyl: Design/equipment failure + human factors
  - Fukushima: Natural disaster+ design failure + human factors
  - Prolonged losses in electricity supply & safety-related equipment due to earthquake/tsunami & late recovery
- **Severe Accident in Multiple Units and for a Long Time**
  - Extensive core melting in three (3) reactors
  - Hydrogen explosion in three (3) reactor buildings
  - Damage in the reactor vessels and containment vessels
  - Threat to the safety of spent fuels in SFPs
  - Several months in escaping from very urgent situation
- **Extensive Contamination of Atmosphere, Land and Sea due to the Release of Radioactive Materials**
  - Large radioactivity release: 10~20% of Chernobyl, INES Level 7
  - No immediate casualty due to radiation exposure
  - Extensive contamination & ~115,000 evacuees

Successful in minimizing radiation exposure; but extensive contamination, societal crisis & enormous economic impact

Fukushima Accident (3)

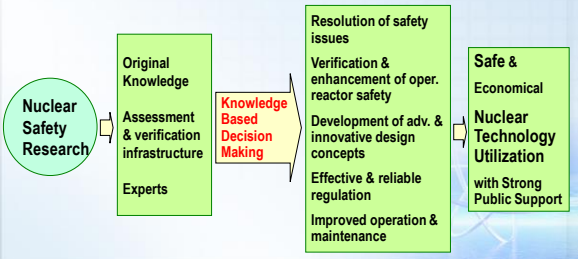
❑ Major Technical Lessons/Issues

- Design basis external events
- Prolonged station blackout and emergency power
- Reactor parameter monitoring during accidents
- Availability of ultimate heat sinks
- Passive safety systems in emergency cooling
- Accident management
- Hydrogen control
- Safety of spent fuel storage
- Probabilistic safety assessment
- Plant siting and site layout

Nuclear Safety Research (NSR) in Korea (1)

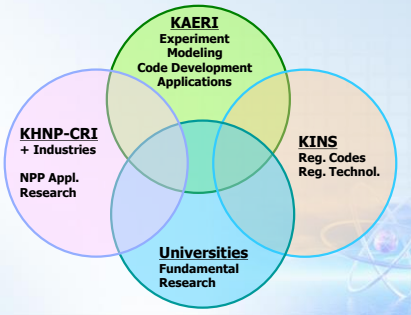
❑ Nuclear Safety Research

- **Scientific investigation and technology development for assessment, verification & improvement of nuclear safety**



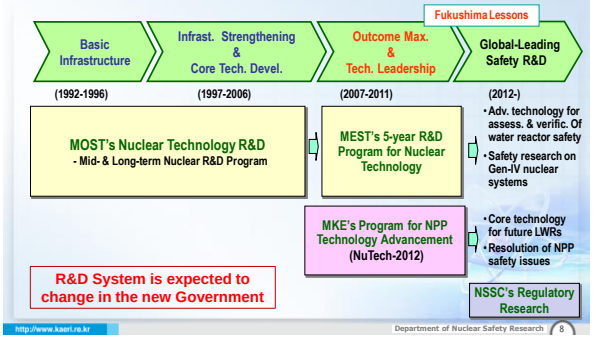
Nuclear Safety Research (NSR) in Korea (2)

❑ Nuclear Safety Research in Korea



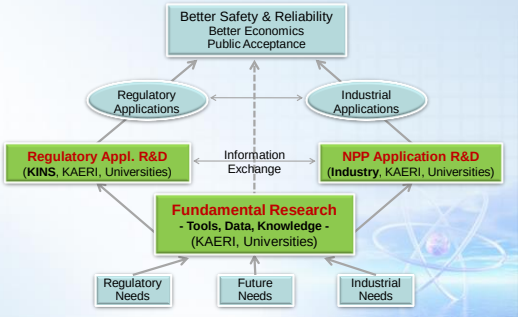
Nuclear Safety Research (NSR) in Korea (3)

❑ National R&D Programs on Nuclear Safety



Nuclear Safety Research (NSR) in Korea (4)

❑ NPP Safety Research & Applications



KAERI's NSR after Fukushima Accident (1)

❑ Basic Directions

- **Incorporation of Lessons from Fukushima Accident**
  - Beyond DBA or Design Extension Conditions
  - Severe accident mitigation & management
  - Dispersion & environmental/human impacts of radioactive materials
  - Risk assessment methodology covering external & multi-unit events
  - Application of passive & inherent safety features
- **Production/Supply of Reliable & Best Outputs to Regulator & Industry for Knowledge-Based Decision Making**
- **Maximum Utilization of Existing R&D Infrastructure**
  - Hardware, Software, Manpower, etc
- **Close Collaboration with Domestic Organizations & Experts**
  - Effective utilization of resources
  - Effective transfer & utilization of the best available knowledge
- **Effective International Collaboration**
  - OECD/NEA, IAEA, etc.
  - Active participation & hosting of international cooperative programs

KAERI's NSR after Fukushima Accident (2)

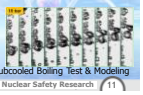
❑ Thermal-Hydraulic Safety

- **Securing Ultimate Heat Sinks for Severe Accident Prevention**
  - Integral simulation of extreme situations (e.g., Prolonged SBO) using the ATLAS facility
  - Development/verification/assessment of passive safety features for advanced reactor systems
  - Coolability of deformed fuels: tests & analyses
- **Advanced Simulation of T/H Behaviors**
  - Development & application of component T/H analysis code, CUPID
  - Coupled analysis of neutronics, component T/H, and system T/H
  - Development of advanced physical models based on high-precision experiments


ATLAS


Deformed core + Fuel relocation


Pool Mixing Test & Analysis for Passive System


Subcooled Boiling Test & Modeling

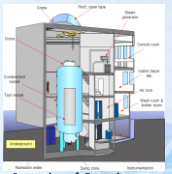
KAERI's NSR after Fukushima Accident (3)

❑ **Severe Accident: Develop Effective Mitigation Measures**

Develop Severe Accident Analysis Code and Methodology: COMPASS+SPACE

TROI : OECD/SERENA Steam Explosion

VESTA: Corium-Structure Interaction



Integrity of Containment: Hydrogen, Filtered Venting, Fission Product

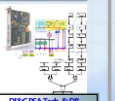
KAERI's NSR after Fukushima Accident (4)

❑ **Risk Assessment & Management**

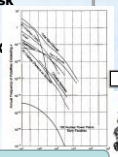
- **Full-Scope Risk Assessment Framework**
  - Internal(including fire/flooding)/ external events (seismic, tsunami, airplane crash, and other external events such as the super typhoon, etc.)
  - Full-power/low-power/shutdown mode PSA
  - Assessment of SFP risks & multi-unit risk
  - New system characteristics: passive systems, digital I&C, etc.
  - Improvement of the PSA engine, FTREX
- **Site Risk Profiles for Korean NPPs**
- **The technical basis for the integrated EOP/SAMG/EDMG and risk-informed Emergency Preparedness**

Development of Basic PRA Technology

Sim.-based HRA Handbook



DI&C PSA Tech. & DB



FTREX 64 bit

Development of Korean Total Site Risk Profile

KAERI's NSR after Fukushima Accident (5)

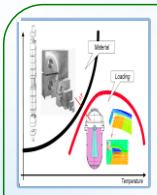
❑ **Environmental Radiation Safety**

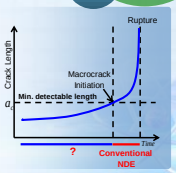
- Evaluation of radionuclides behavior in surface, ocean and atmosphere in long-range area: LADAS, LODAS codes
- Assessment of radiation impact to human and biota and environmental transport of radionuclides: ECOREA, ECOREA-H, K-BIOTA codes
- Development of radiological impact assessment models resulting from accidental and routine releases: FADAS, METRO-K codes
- Research about radiation resistance-related genomics
- Low dose effect of radiation, H-3 biological effect
- Retrospective radiation dosimetry and measurement

KAERI's NSR after Fukushima Accident (6)

❑ Materials Safety

Enhance Long Term Operation Safety of Nuclear Materials





PTS Safety Simulation & Modeling

SCC Prediction & Mitigation

Eearly Diagnosis

KAERI's NSR after Fukushima Accident (7)

❑ Spent Fuel Safety at LOC

- **Objectives**
  - To study spent fuel behavior under loss of cooling conditions in SFP
  - To derive criteria for SFdegradation under loss of cooling conditions
  - To measure source term from degraded spent fuel

- **Just Started in 2012**
  - Separate effect tests for pellet oxidation and fragmentation behavior
    - ✓ Air or mixture (steam & air) environments, temp. (350 ~ 1400℃)
    - ✓ Results: Oxidation kinetic data , Existing model assessment

- **Work to be done in 2013-2016**
  - - Separate effect tests for cladding degradation behavior
  - - Integral tests for fuel degradation behavior
  - - Derivation of fuel degradation criteria in spent fuel pool
  - - Measurement of fission product release form degraded spent fuel

KAERI's NSR after Fukushima Accident (8)

❑ International Collaboration

- **Post-Fukushima Activities**
  - Active participation in IAEA/UNSCEAR/NEA programs
  - Bilateral cooperation with Japanese organizations
- **OECD/NEA Programs**
  - Active participation of CSNI & CNRA Programs/Projects
  - Hosting of selected programs: ISP-50 with ATLAS, SERENA Project with TROI, Rod bundle CFD benchmark with MATiS, etc.
  - Proposal of new projects: OECD-ATLAS (proposed), SERENA-2 (under preparation) and others
- **IAEA Programs**
  - Participation of CRPs in various NSR areas
- **Bilateral Cooperation with Foreign Organizations**

Concluding Remarks

- Securing a high level of safety is a pre-requisite for development and utilization of nuclear technology
- Many aspects of the Fukushima accident had already been known or investigated
  - Multiple failure of safety systems, passive cooling, hydrogen explosion, molten core cooling, etc.
  - Even the existing knowledge/information was not fully utilized in decision making
  - No immediate fatality was largely due to existing knowledge
- Reflection of Fukushima Lessons in KAERI's new NSR Program (2012~)
- Harmonized prevention and mitigation of severe accident through "knowledge-based decision making"
  - Investigation/prevention of scenarios leading to severe accidents
  - Behavior of cooling systems for reactor core and spent fuel pool
  - Understanding and mitigation of severe accident phenomena
- Safety research should provide a 'reliable' and 'best-achievable' knowledge base

Acronyms

APR1400	Advanced Power Reactor 1400 MWe
DBA	Design basis accident
INES	International Nuclear & Radiological Event Scale
ISP	International Standard Problem
KAERI	Korea Atomic Energy Research Institute
KHNP-CRI	Central Research Institute of Korea Hydro & Nuclear Power Co.
KINS	Korea Institute of Nuclear Safety
MEST	Ministry of Education, Science & Technology
MKE	Ministry of Knowledge Economy
MOST	Ministry of Science & Technology
NEA	Nuclear Energy Agency
NSR	Nuclear safety research
NSSC	Nuclear Safety & Security Commission
OPR1000	Optimized Power Reactor 1000 MWe
PWR	Pressurized water reactor
PHWR	Pressurized heavy water reactor
SBO	Station Blackout
SERENA	Steam Explosion Resolution for Nuclear Applications
SFP	Spent fuel pool
TMI	Three Mile Island