Status of Fast Reactor and Pyroprocess Technology Development in Korea

International Conference on Fast Reactors and Related Fuel Cycles (FR09), Kyoto, Japan

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Ministry of Education, Science and Technology

Outline

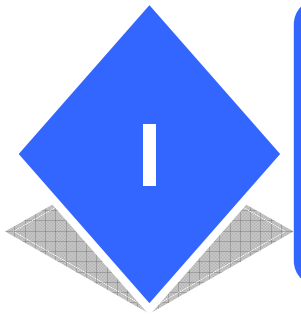
I Korean Nuclear Power Program

II SFR & Pyroprocess Development Program

III SFR Technology Development

IV Pyroprocess Technology Development

V Summary



Korean Nuclear Power Program

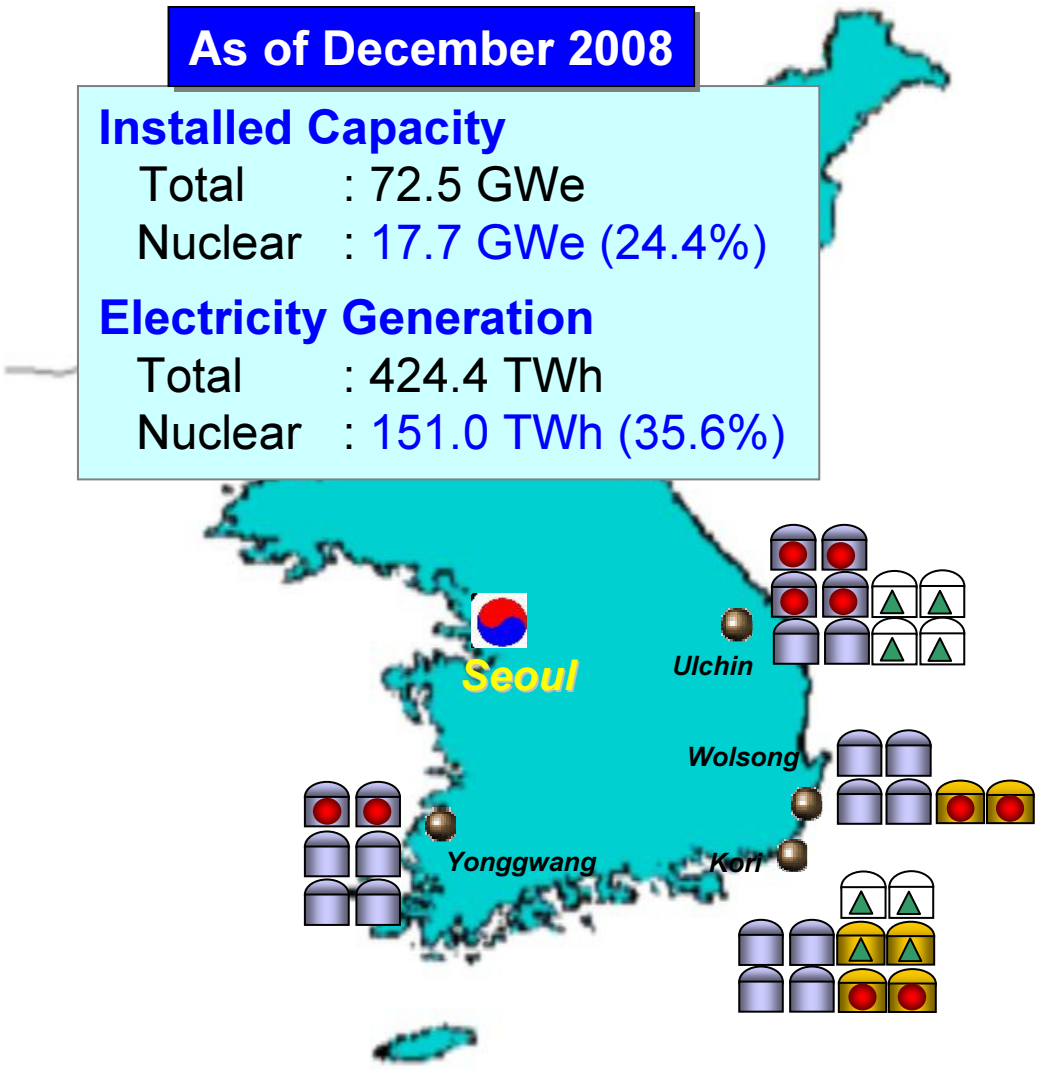
I.1 Current Status of NPPs

I.2 Status of Spent Fuel Storage

I.3 Radioactive Waste Management Law

I.4 Reactor Transition Scenario

I.1 Current Status of NPPs



- In Operation
  - 20 Units
    - 16 PWRs (6 OPR1000)
    - 4 PHWRs at Wolsong
- Under Construction
  - 4 OPR1000
  - 2 APR1400
- Planned by 2022
  - 6 APR1400

In operation
Under construction
Preparation for Construction
OPR1000
APR1400

I.2 Status of Spent Fuel Storage

- On-site SF storage limit will be reached from 2016
- Decision making process for interim SF storage

NPP Sites	As of December 2008			Expansion Plan	
	Cumulative Amount (MTU)	Storage Capacity (MTU)	Year of Saturation	Storage Capacity (MTU)	Year of Saturation
Kori	1,685	2,253	2016	2,253	2016
Yonggwang	1,623	2,686	2016	3,528	2021
Ulchin	1,294	2,328	2017	2,328	2017
Wolsong	5,481	5,980	2009	9,155	2017
Total	10,083	13,247		17,262	

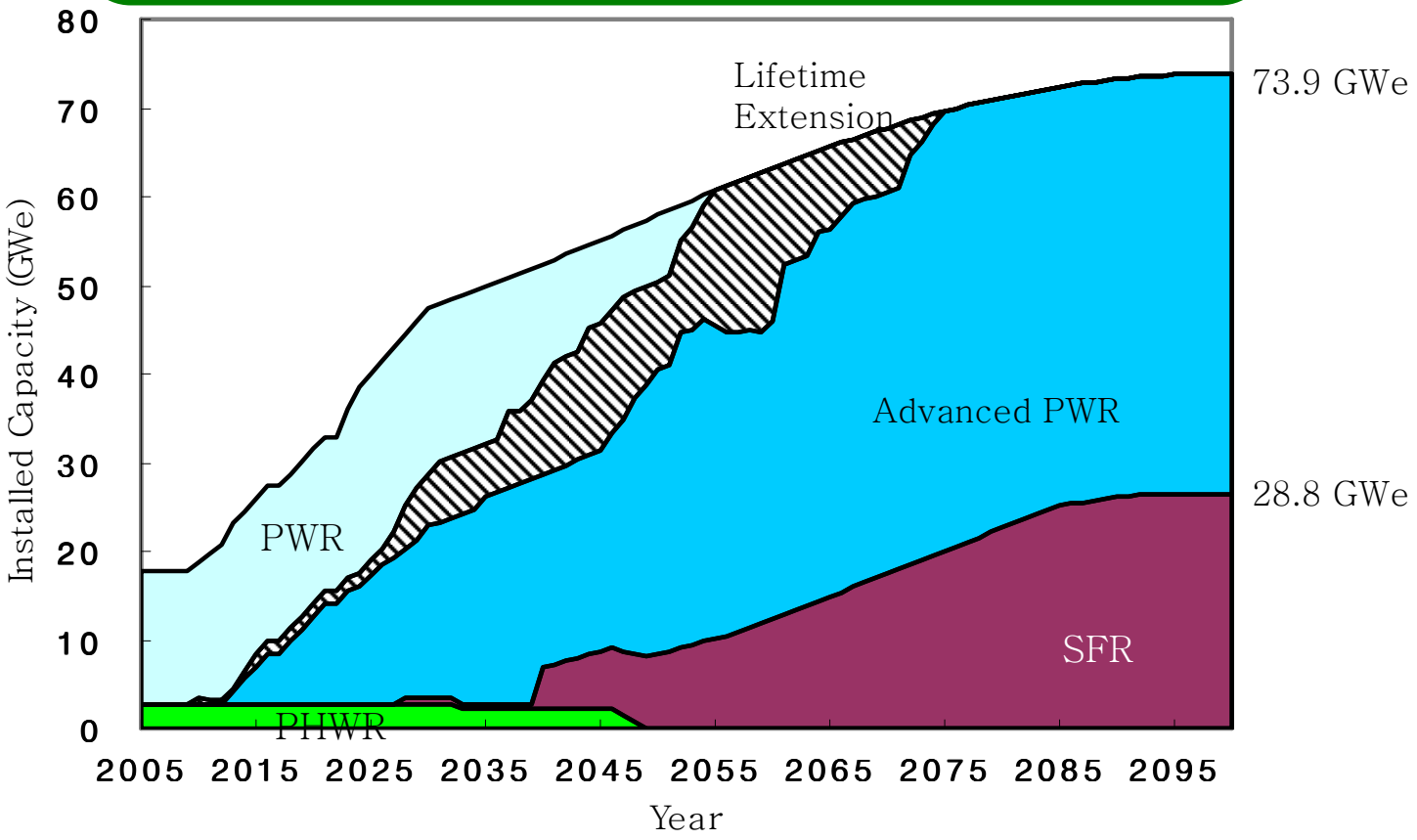
I.3 Radioactive Waste Management Law

- National Assembly passed the Radioactive Waste Management (RWM) Law on 26 February 2008
  - For safe management of radioactive wastes including spent fuels
- Main Contents of the Law
  - Establishment of a basic plan for RWM with the approval of the Korea Atomic Energy Commission
  - Establishment of Korea Radioactive-waste Management Corporation (KRMC) on 1 Jan 2009
  - Establishment of RWM fund
    - Low and intermediate level radioactive waste
    - Spent fuel
- Proclamation of KPSE in September 2008 by MKE

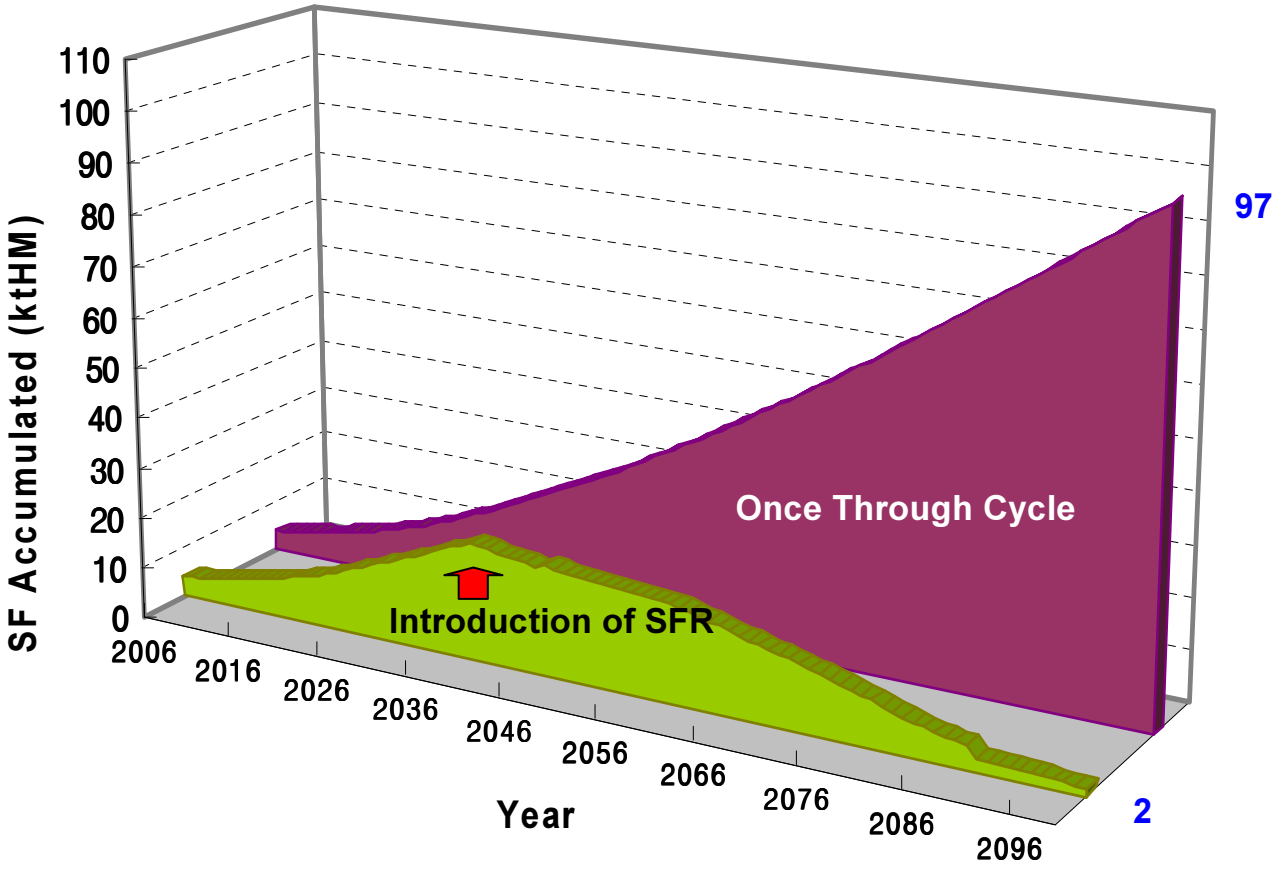
I.4.1 Reactor Transition Scenario - KAERI Study

◆ **Total electricity generation growth rate**
- 2006~2030 : Planned
- 2031~2050 : 1.0%/year
- 2051~2100 : Reduced to 0%/year in 2100

◆ **Nuclear share of 59.0% after 2030**

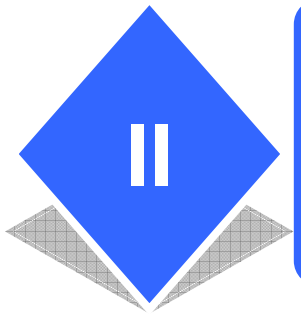


I.4.2 Spent Fuel Inventories - KAERI Study



Cumulative PWR spent fuel

(Capacity Factor 85%)



SFR & Pyroprocess Development Program

II.1 Long-term Development Plans

II.2 Long-term Plan for SFR and Pyroprocess

II.3 Long-term Plan for Metal Fuel

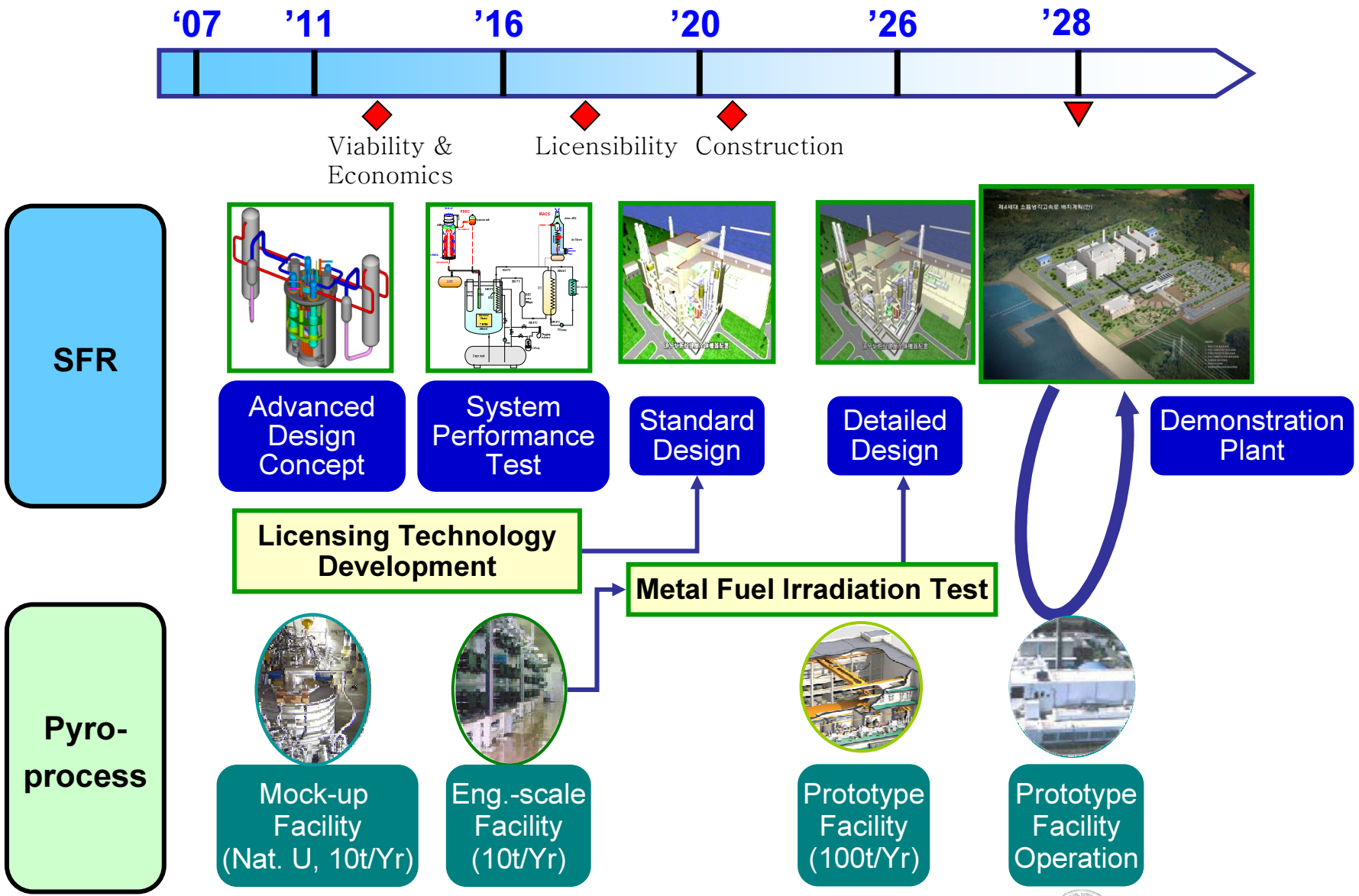
II.1 Long-term Development Plans

- The Korea Atomic Energy Commission approved Long-term Development Plans for Future Reactor Systems on December 22, 2008
  - Include Plans for SFR, Pyroprocess and VHTR
  - Intend to provide a consistent direction to long-term R&D activities

- Detailed Implementation Plan is now being developed
  - Schedule, deliverables, responsibilities and resources

- Long-term Plans are implemented through Nuclear R&D Programs of the NRF with funds from the MEST

II.2 Long-term Plan for SFR and Pyroprocess



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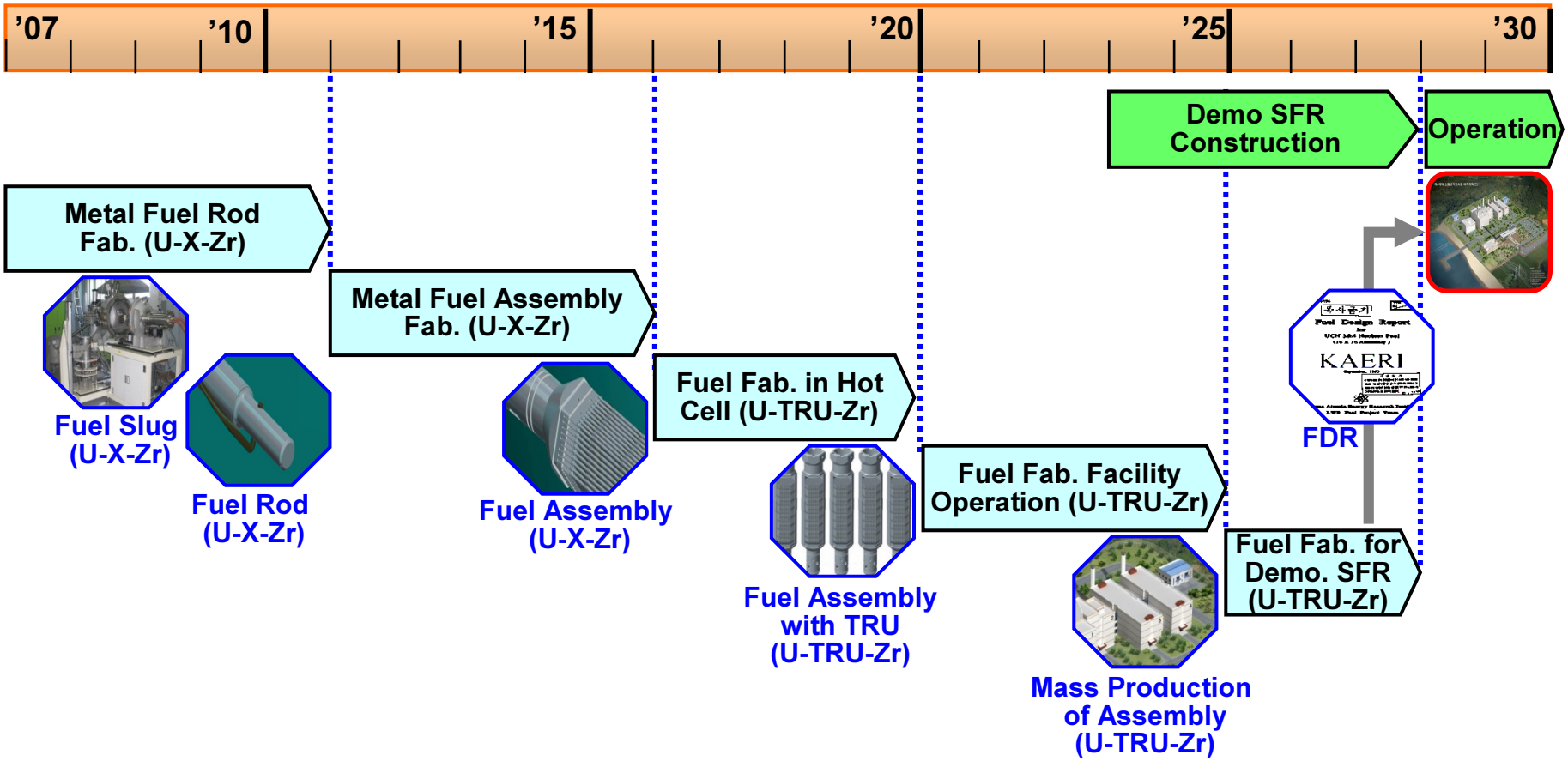
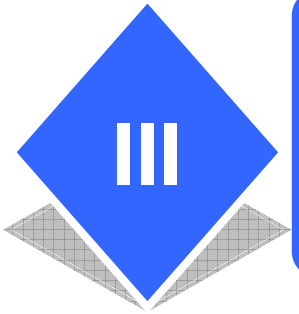
II.3 Long-term Plan for Metal Fuel





SFR Technology Development

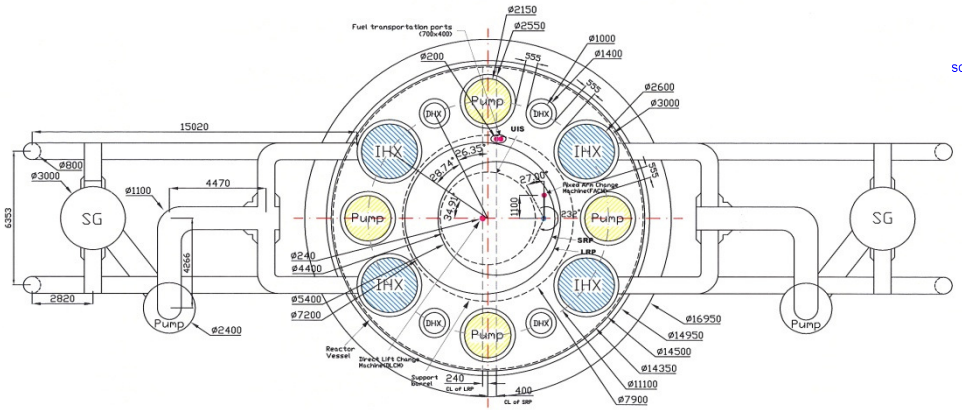
III.1 Advanced Concept Design Studies

III.2 R&D Activities for Advanced SFR

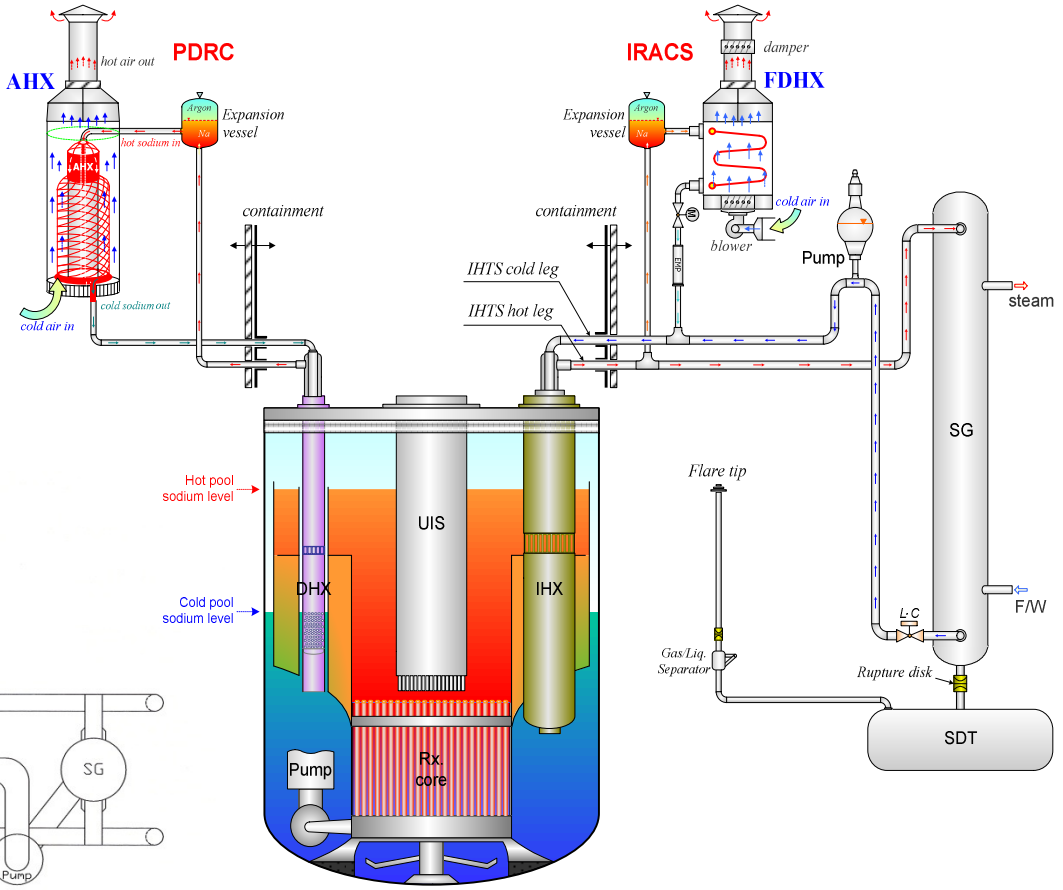
III.1 Advanced Concept Design Studies

Key Design Features

- ❑ 1200MWe, Pool-type Reactor
- ❑ Fuel : U-TRU-Zr
- ❑ Core I/O Temp : 390/545℃
- ❑ DHR System : PDRC
- ❑ 2-loop IHTS/SGS
- ❑ Net Efficiency : 39.4%



Conceptual NSSS Layout



Heat transport system of advanced pool type SFR

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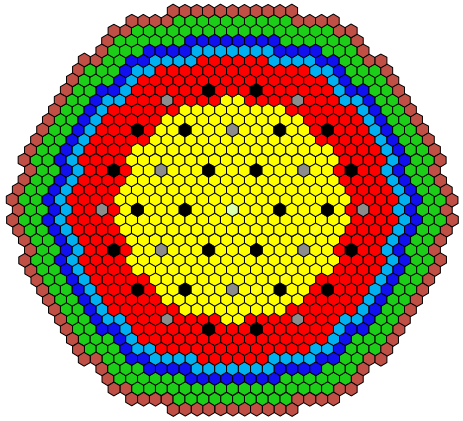
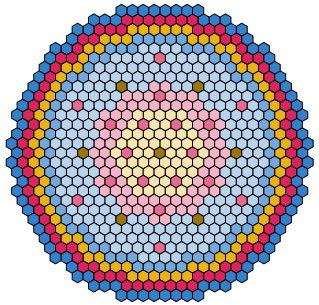
III.1.1 Core Design



Inner Core	318
Outer Core	306
Primary CR	24
Secondary CR	12
Reflector	96
B_4C Shield	102
IVS	222
Radial Shield	120
Empty CR	1
Total	1201

1,200 MWe Breakeven Core



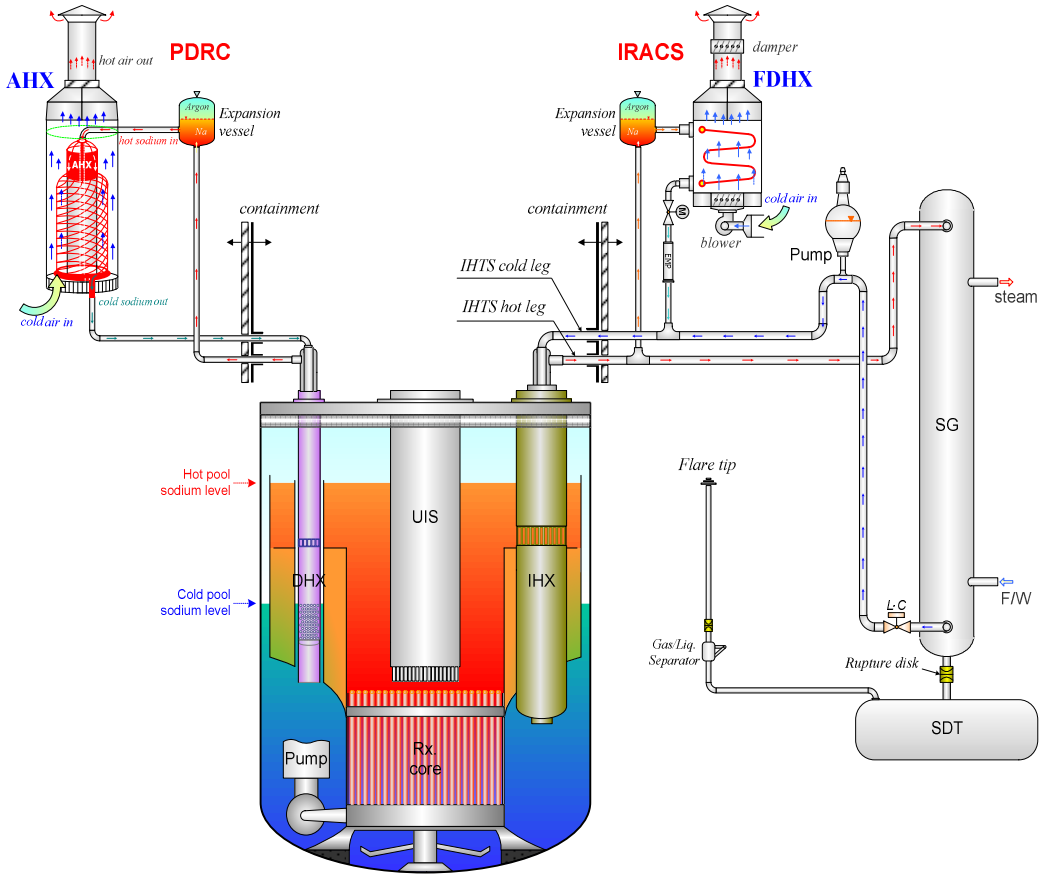
Inner Core	54
Middle Core	72
Outer Core	198
Primary CR	18
Secondary CR	7
Reflector	72
B_4C Shield	78
IVS	84
Radial Shield	90
Total	673

600 MWe TRU Burner Core

Core Design Parameters	Breakeven Core	TRU Burner Core
Power (MWe)	1,200	600
Core height (cm)	80	89
No. of fuel regions	2	3
Cycle length (EFPM)	18	11
Charged TRU enrichment (IC/MC/OC, wt%)	13.16/ - /16.79	30.0
Conversion ratio (fissile/TRU)	1.0/ -	0.74/0.57
Sodium void reactivity (EOEC, $)	7.25	7.50

III.1.2 Heat Transport System Design

- **Design studies for improved safety, economics and performance**
- **Reference design**
  - Pool-type reactor
  - Superheated steam cycle
  - Straight double wall tube SG
  - 2 loop IHTS/SGS
- **Design Options**
  - S-CO_2 Brayton cycle
  - Helical double wall tube SG



Heat transport system of advanced pool type SFR

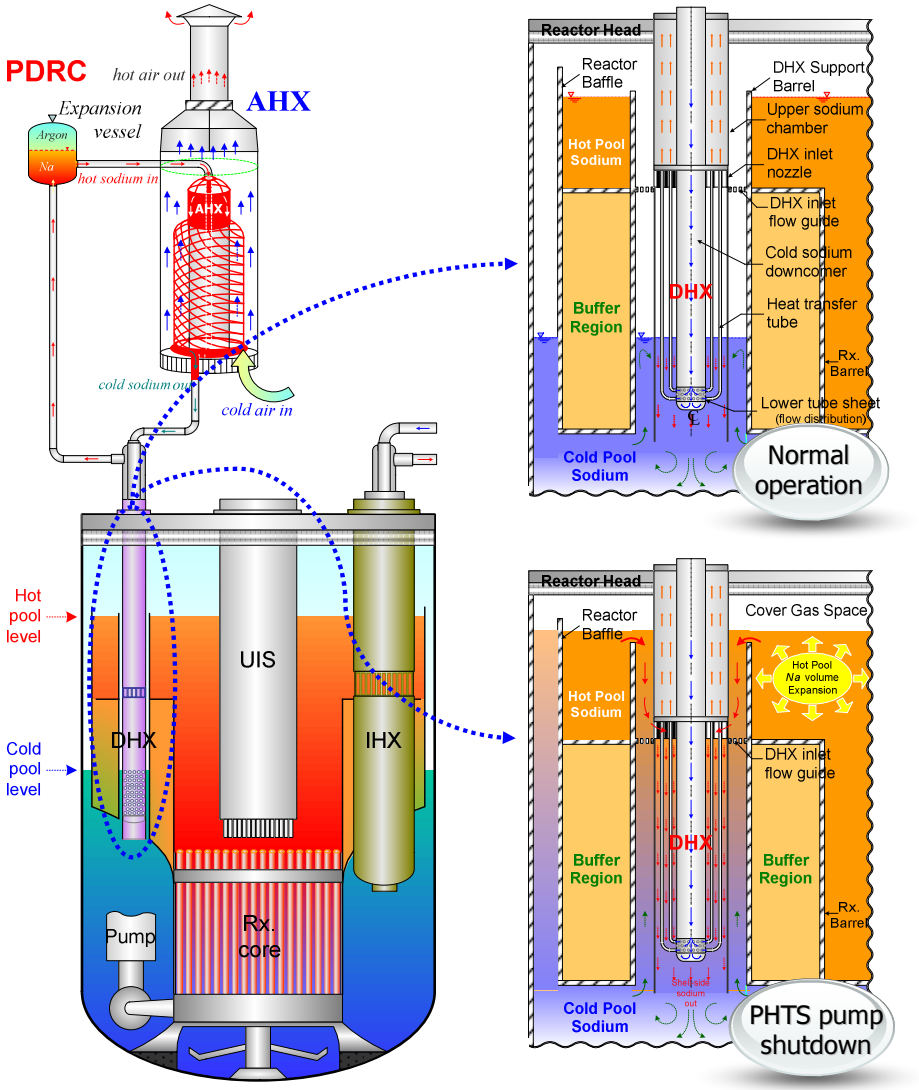
III.1.3 PDRC Design Features

❑ System Design Features

- Elimination of active components
- Operation by natural circulation
- No operator action
- Major components
  - AHX, DHX, expansion vessel and piping

❑ System Operation

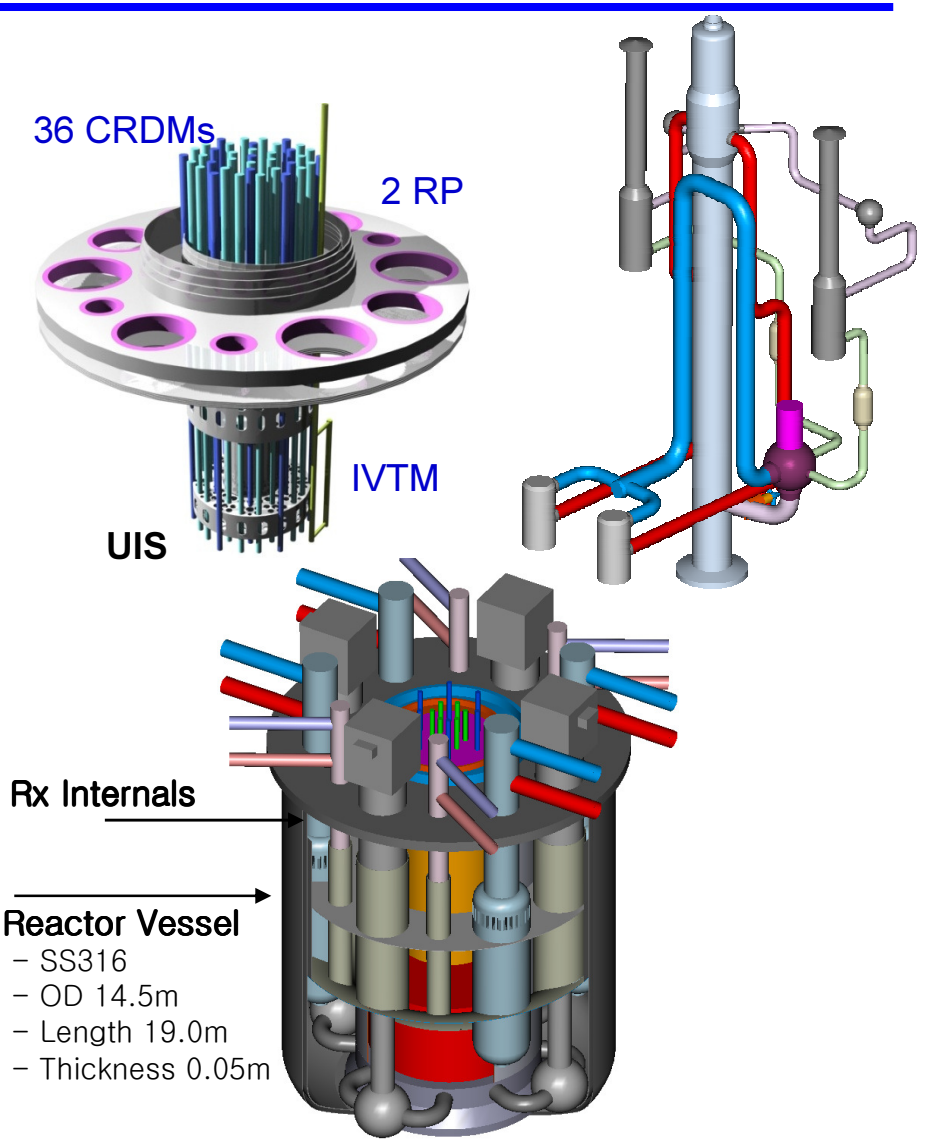
- Normal operation
  - Minimized heat loss enough to prevent sodium freezing
- Primary pump trip
  - Decay heat removal by natural circulation



PDRC design concept

III.1.4 Mechanical Structure System

- **Studies for a cost competitive large scale SFR**
  - Size optimization
  - Large size components arrangement
- **Design Issues**
  - Feasibility of 2 loop layouts with large size equipments
  - Simplified IHTS piping with large piping diameters and SG/pump arrangements
  - Integrated components
- Structural design evaluation to check design feasibility



Conceptual NSSS Design

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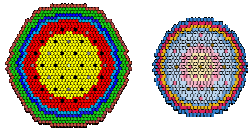
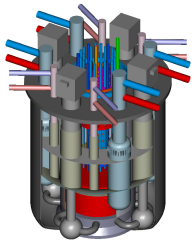
III.2 R&D Activities for Advanced SFR

Advanced Concept Design Studies

- Sustainable and proliferation resistant core

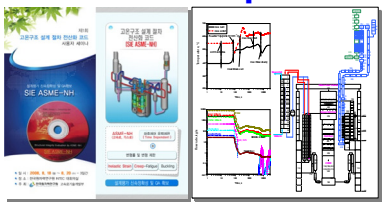


- Economic improvement of fluid and structural system

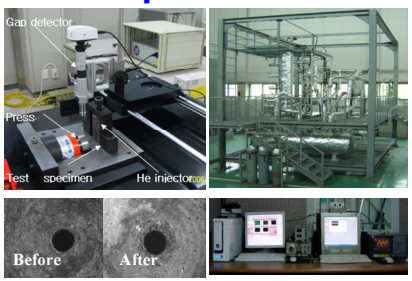


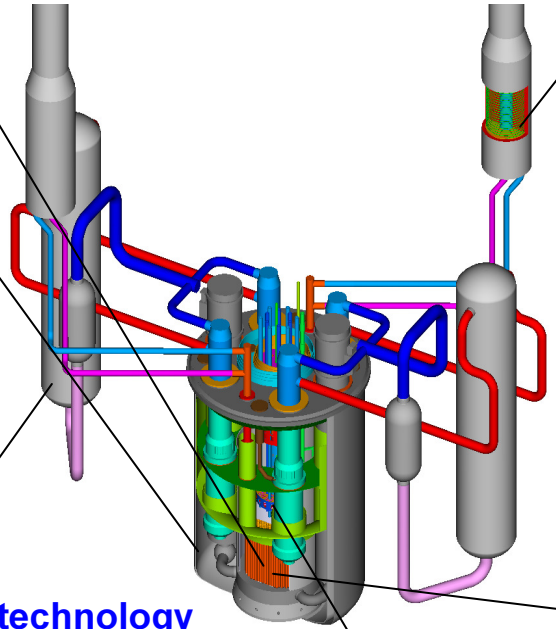
Development of Basic Technologies

- System analysis code development



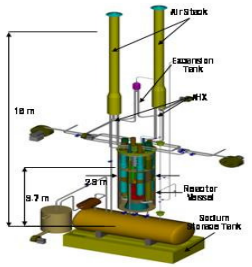
- Sodium technology development



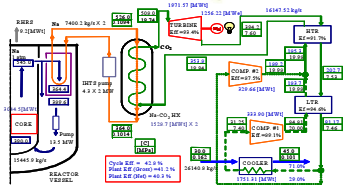


Development of Advanced Technologies

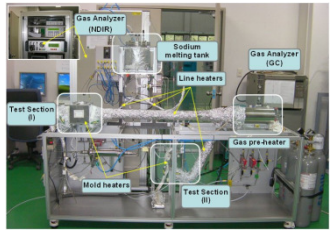
- PDRC experiment



- S-CO_2 Brayton cycle system

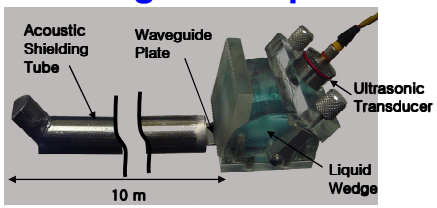


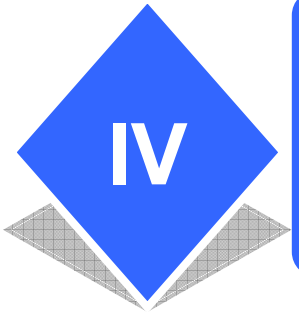
- Na-CO_2 interaction test



- Metal fuel technologies

- Under-sodium viewing technique





Pyroprocess Technology Development

IV.1 Pyro-Processing Technology

IV.2 Pyro-System Engineering Technology

IV.1 Pyroprocessing Research in Korea

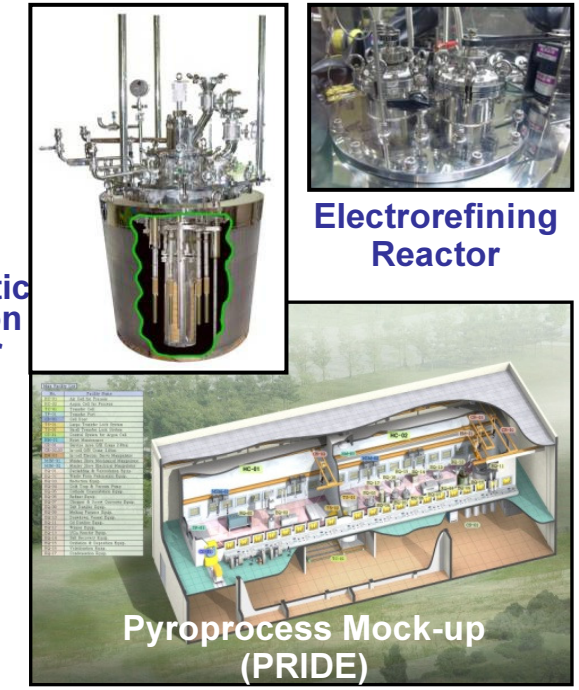
❑ Objective

– To develop pyroprocessing technology for reducing spent fuel volume and providing SFR fuel

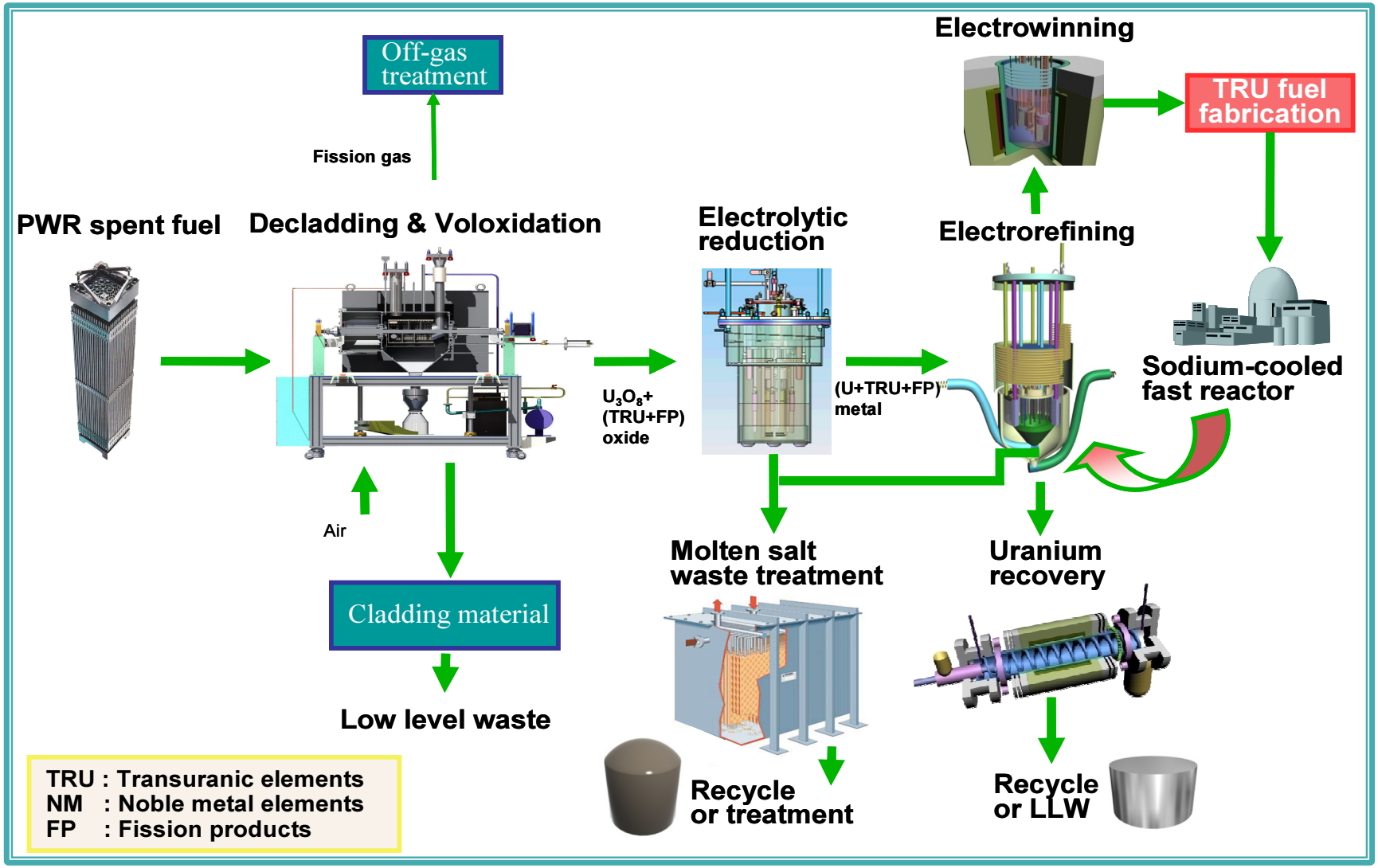
❑ Key R&D Areas

– An integrated pyroprocessing system with
  - 50 kgHM/batch capacity by 2016
  - Waste minimization
  - Realization of high-throughput (HT)

– Including
  - Electrolytic reduction process
  - HT electrorefining and electrowinning process
  - Safeguards technology
  - Pyroprocess mock-up facility design and construction



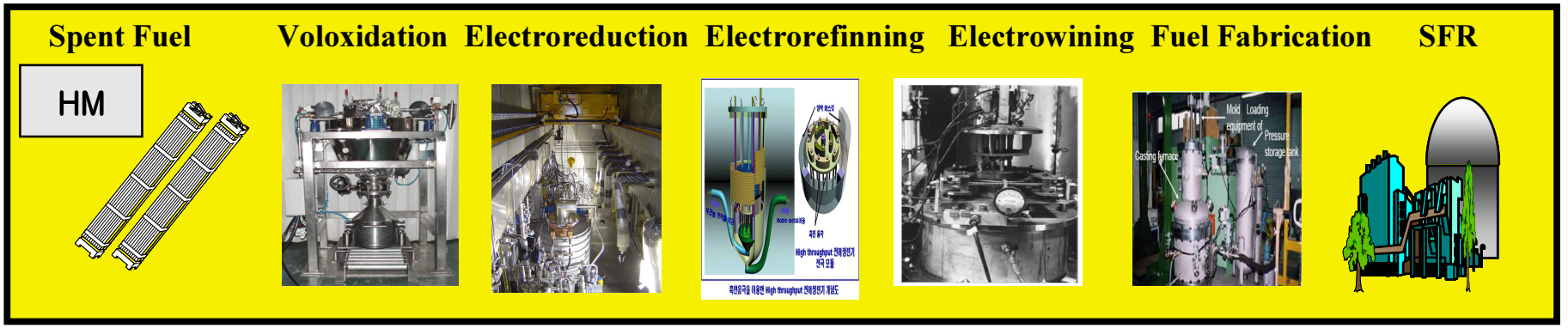
IV.1.1 Flow Diagram of Pyroprocessing (KAERI)



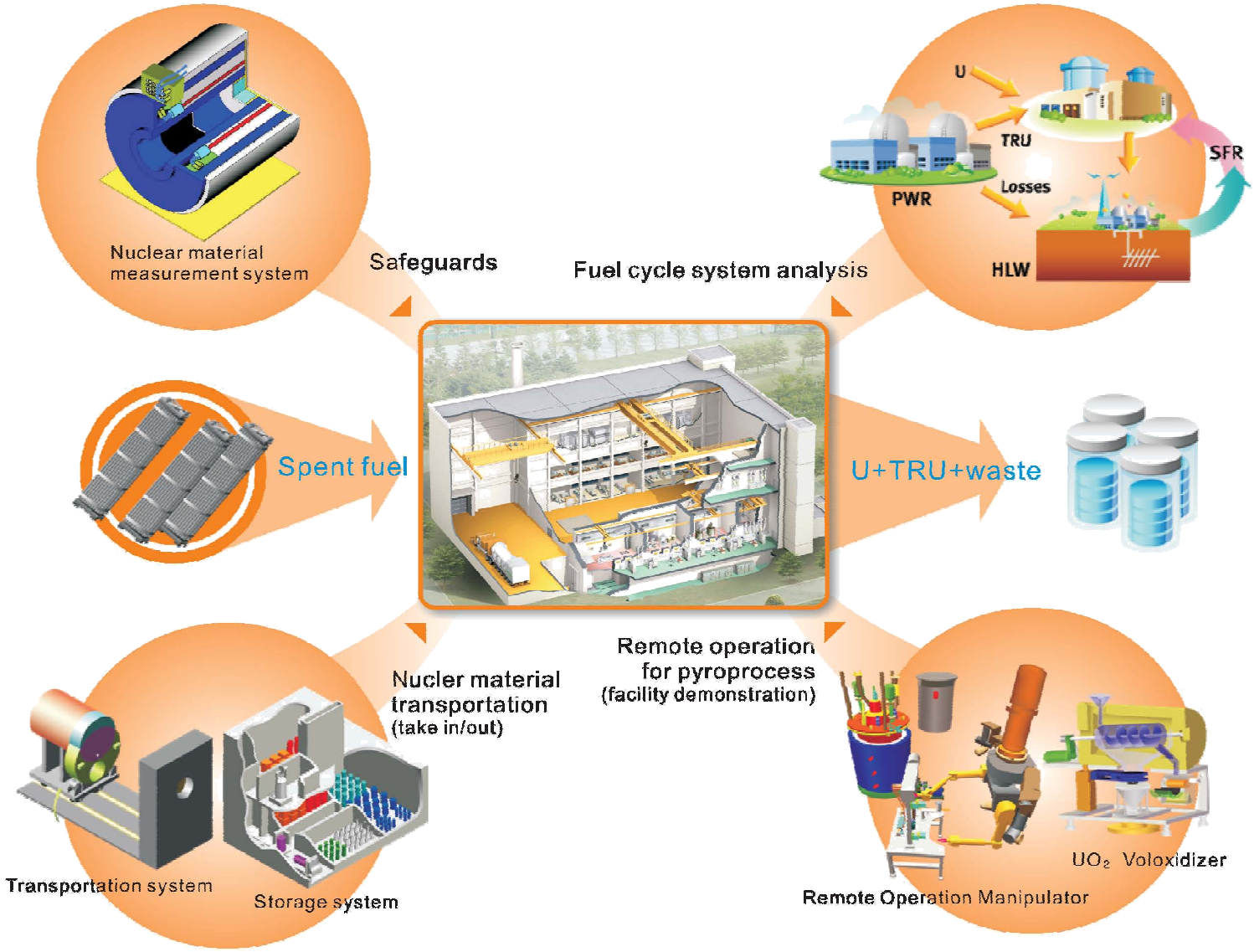
IV.1.2 R&D Issues of Pyroprocessing

- **Purposes**
  - Increase throughput
  - Simple and easy operation mode
  - Reduce waste volume

- **Improvement**
  - Graphite cathode employment to recover U in electrorefining system
  - Crystallization method applied to recover pure salt from waste mixture



IV.2.1 System Engineering Technologies



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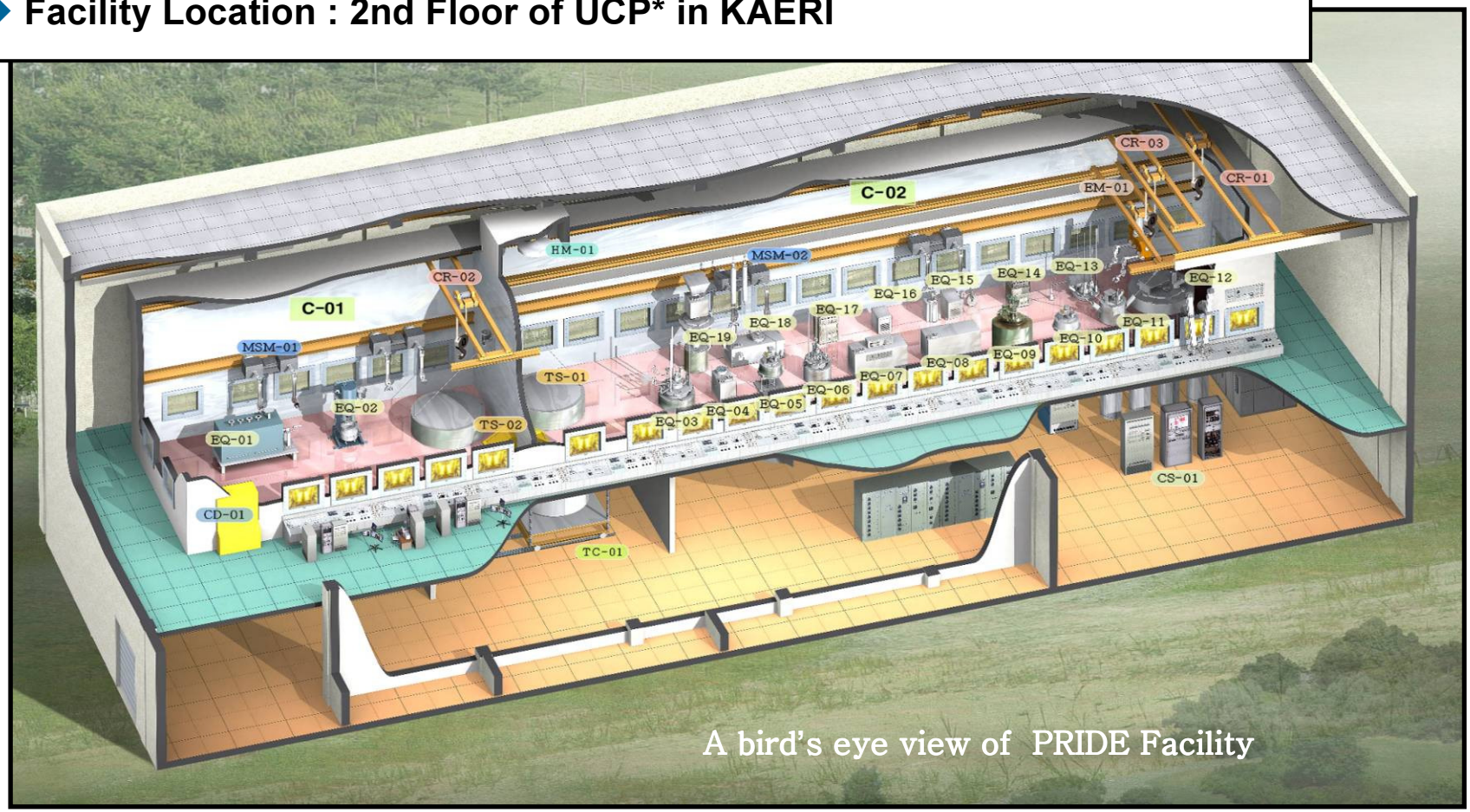
IV.2.2 PRIDE : PyRoprocess Integrated inactive DEmonstration Facility

- Integrated Engineering-scale Mock-up Facility by 2011
- Argon Cell
- Cell Inside Dimension : 40 mL x 4.75 mW x 6.3 mH
- Facility Location : 2nd Floor of UCP* in KAERI



A bird's eye view of PRIDE Facility

* UCP : Uranium Conversion Plant which is now under decommissioning stage.

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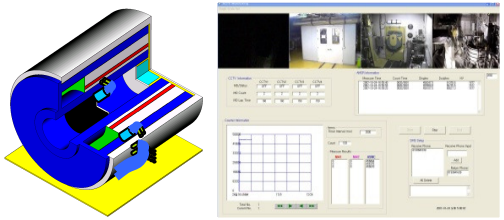
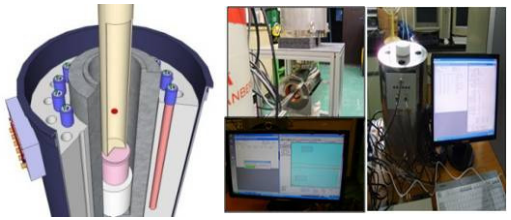
IV.2.3 Safeguards Technology Development & International collaboration

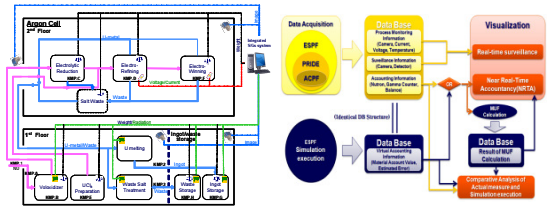
Safeguards Technology for ACPF



NMA Technology for Pyro.



Safeguards Design and Safeguardability Assessment



ACPF : Advanced spent fuel Conditioning Process Facility
NMA : Nuclear Material Accounting, SG : Safeguards
PRIDE : PyRoprocess Integrated inactive Demonstration facility
ESPF : Engineering Scale Pyroprocessing Facility

ACPF (Lab-Scale Electrolytic Reduction)

Establishment of the Safeguards System in the ACPF

PRIDE

Establishment of the Safeguards System in the PRIDE

Establishment of the Safeguards System in the ESPF

◆ Enhancement of PR of ACP

ROK-US PCG Collaboration for SG Tech.

- Support of a Safeguards System for ACPF
- ◆ Regional Collaboration for Transparency
- ◆ Study for Neutron, Gamma, LIBS, SINRD

ROK-US under the KAERI-10 Program

- ◆ NDA System Test at INL
- ◆ Safeguards Study for the KAPF
  - Safeguardability
  - Proliferation Resistance Analysis

ROK-IAEA Collaboration with MSSP

- ◆ Development of Safeguards Approach for Pyroprocessing Plant
- ◆ Facility Design and Plant Operation Features that facilitate the implementation of IAEA Safeguards

PR: Proliferation Residence
LIBS : Laser Induced Breakdown Spectroscopy
SINRD : Self Indication Neutron Resonance Densitometer

V. Summary

- **Long-term Plan for SFR and Pyroprocess Development** was approved by the KAEC in December 2008
  - Construction of PRIDE facility by 2011
  - Standard design approval of demonstration SFR by 2020
  - Construction of KAPF facility by 2025
  - Construction of demonstration SFR by 2028

- Activities for the **Development of Advanced SFR Concept**
  - Advanced concept design studies
  - Development of advanced technologies
  - Development of basic technologies

- Activities for the **Development of Pyroprocess Technology**
  - PRIDE will be used for testing the integrity of unit process, the adaptability of remote operation, and safegaurdability at an engineering scale