Introduction to a Critical Assembly Project for Advanced Reactor Physics Education in Korea

Sang-Ik Wu (siwu@kaeri.re.kr)
Byung-Cheol Won, Seung Hyun Song, Yeon Sik Yoo, Beomwoo Park

18 Jun 2025

KAERI Korea Atomic Energy Research Institute

For Building Future R&D Capacity

Background

- ✓ The competition for technology development to take the lead in the next-generation nuclear reactor system, such as SMR, is intensifying.
- ✓ It is necessary to establish a manpower training system to take a leap forward in the domestic nuclear industry and strengthen international technological competitiveness.
- ✓ In Korea, Kyunghee university's 'Reactor Research & Education Center' have been operating a critical facility for nuclear education since 1983.
- ✓ However, the need for state-of-the-art equipment has long emerged.
- ✓ New national project to establish a Advanced Critical Assembly for Education (ACE) has been launched from 2024 led by the KAERI.
- ✓ The ACE is located at the King Munmu Advanced Research Institute for Nuclear Science (MARINS) in Gyeongju, South Korea

Project Overview

Korea Atomic Energy Research Institute

Title ACE (Advanced Critical Assembly for Education)

Goal To establish a low-power($10W_{th}$) Critical Assembly for education and to develop a Global Human Resource Development Program

Period 2024~ 2028 (32M-US$) **Site** 4,400㎡

Facilities 2 Facilities
: Critical Assembly Bldg., Education & Research Bldg.

Title MARINS (Munmu* Advanced Research Institute of Nuclear Science)

Goal 2nd campus of the KAERI that enhance innovative reactor systems

Period 2021~ 2027 (Phase1) **Site** 2,200,000㎡

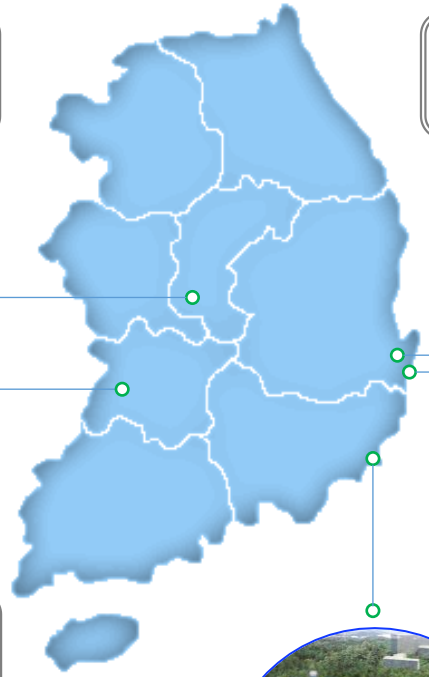
Facilities 17 Facilities including SMR Test Facility
: SMR Test Facility(1), Infratructures(8), Suport Facilities(6), Others(2)

Korea Atomic Energy Research Institute

Branches and Facilities Across Korea

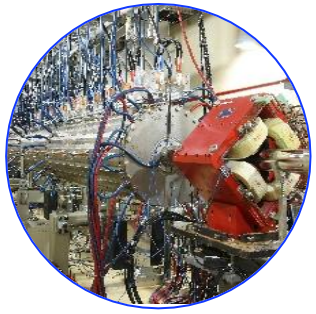
Head Quarter

KAERI
(Daejeon)



KOMAC
(Gyeongju)

Proton Accelerator



ARTI
(Jeongeup)

Advanced Radiation Technology Institute

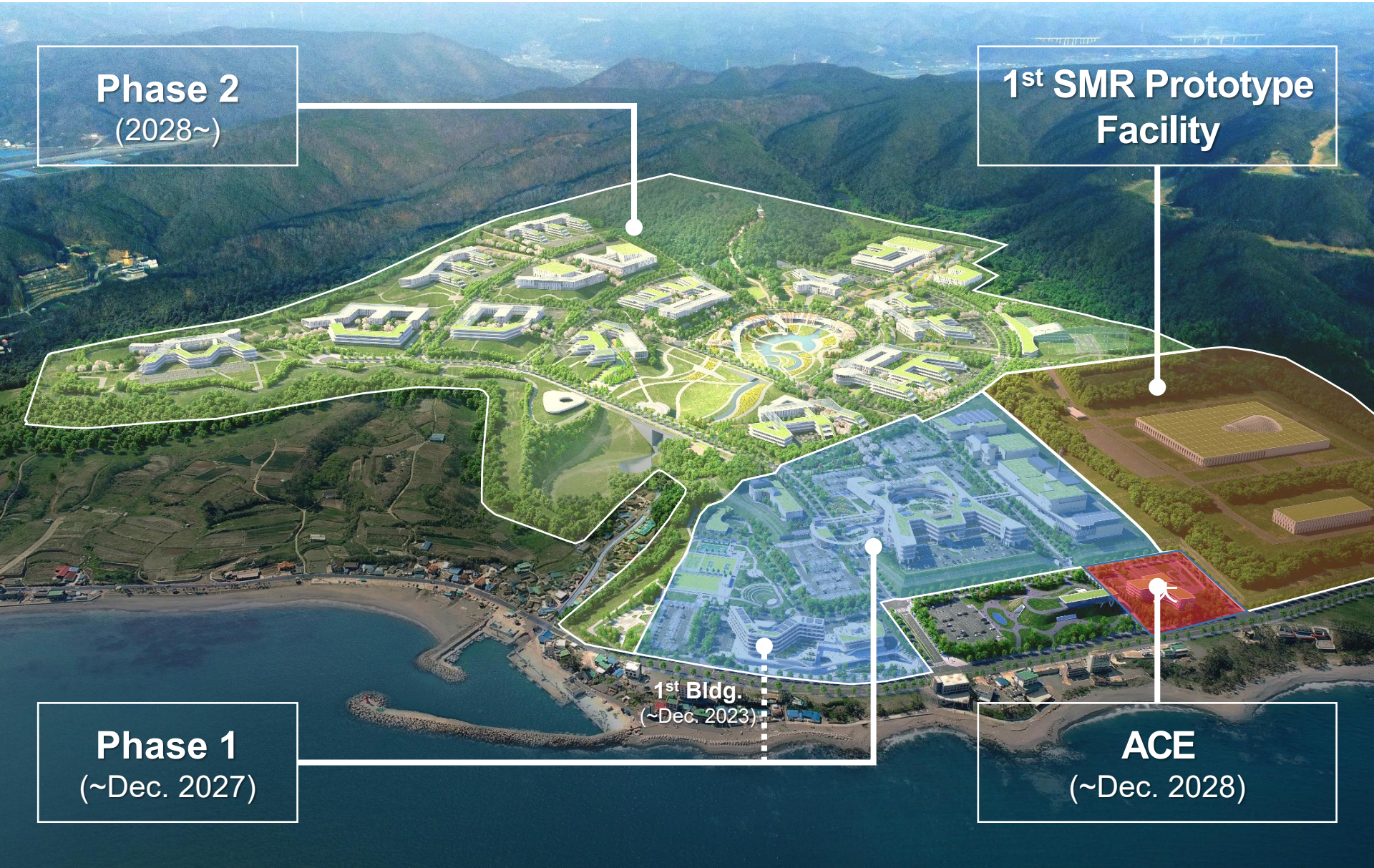
KJRR
(Busan)
Under Construction

Kijang Research Reactor

MARINS
(Gyeongju)
Under Construction

2nd Campus of KAERI

Site Arrangement of MARINS



View as of May 2025

View as of May 2025

Core Design

Design Requirements

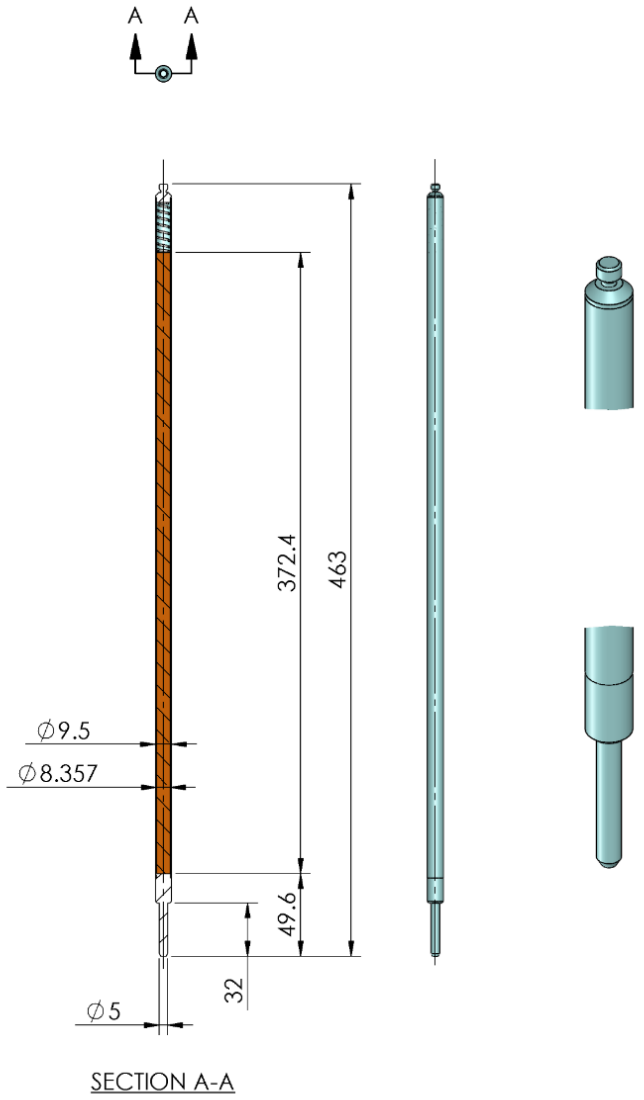
Contents	Requirements
Maximum power	10 W_{th}
Reactor	Open-pool type
Fuel	Rod type, UO_2 (same with APR1400)
Moderator/Reflector	H_2O
Reactivity control	Control rod (B_4C)
First shutdown system	Drop of control rod
Second shutdown system	Dumping of water
Excess reactivity	< 500 pcm
Shutdown margin	> 1000 pcm
Isothermal temperature coefficient	Negative (> 15 ℃)
Neutron flux	< 10^8 n.cm^2/sec

Core Design

Fuel Rod

Fuel	
Material	UO_2
Enrichment (wt.%)	4.1
Pellet diameter (cm)	0.8192
Pellet length (cm)	0.98
Active length (cm)	37.24 (38 pellets)
Volume of active region (cm^3)	19.628
UO2 stack density (g/cm^3)	10.313
Maximum number of fuel rods	570
Total U-235 mass (kg)	4.17
Total UO_2 mass (kg)	115.38

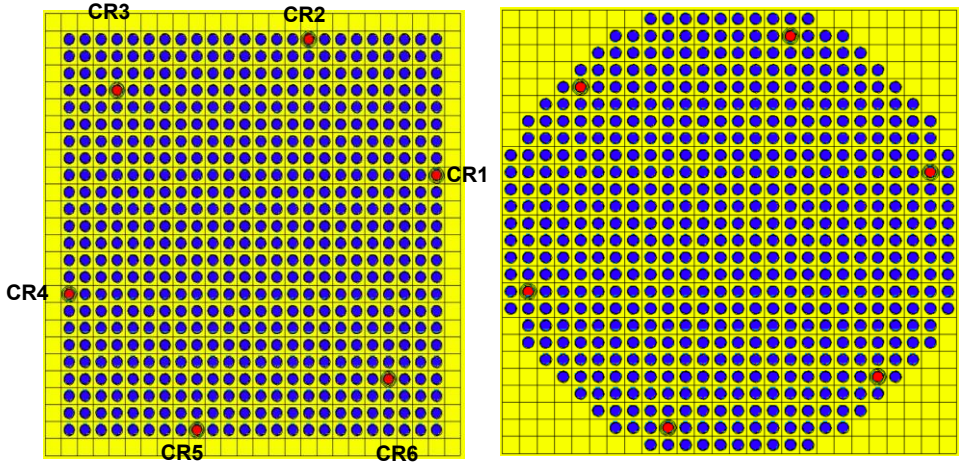
Cladding	
Material	ZIRLO
Diameter, Inner/Outer (cm)	0.8357 / 0.95
Length (cm)	46.3



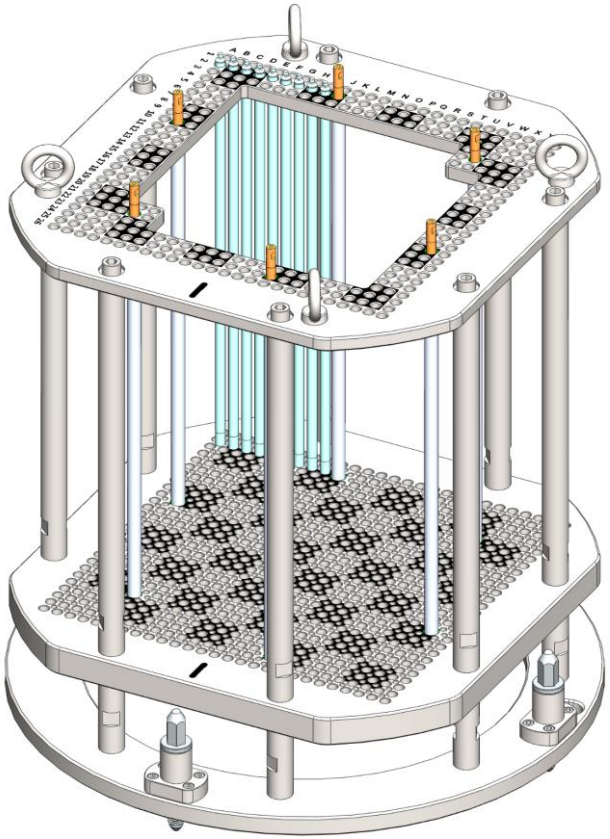
Core Design

Core Configuration

- **Two types of basic core**
  - S(quare)-core : 570 fuel rods, 6 control rods
  - C(circle)-core : 550 fuel rods, 6 control rods
- **Grid plates**
  - 26x26 holes for fuel rods and control rods
  - Guide tubes for 6 CRs in fixed positions



<Fuel loading of S-core and C-core>



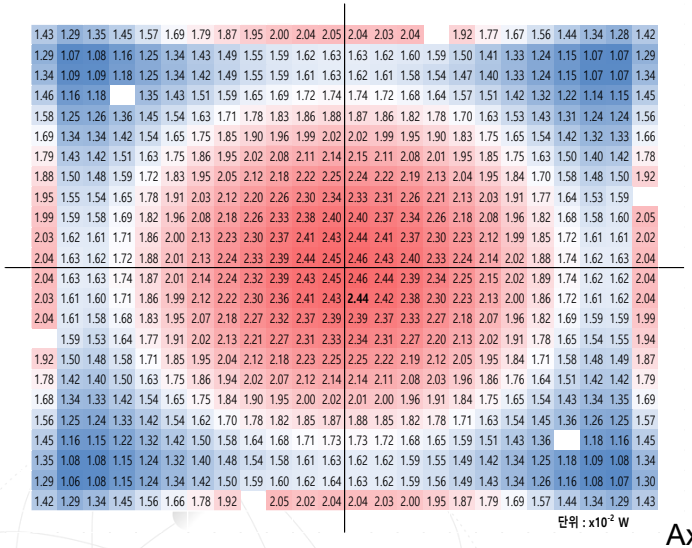
<Fuel rods, control rods, grid plates>

Neutronic Characteristics

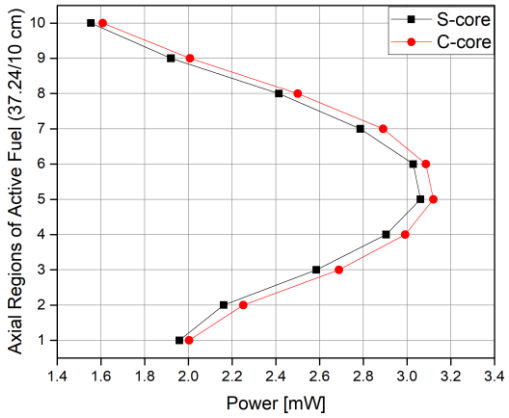
Power distribution

Power peaking factor

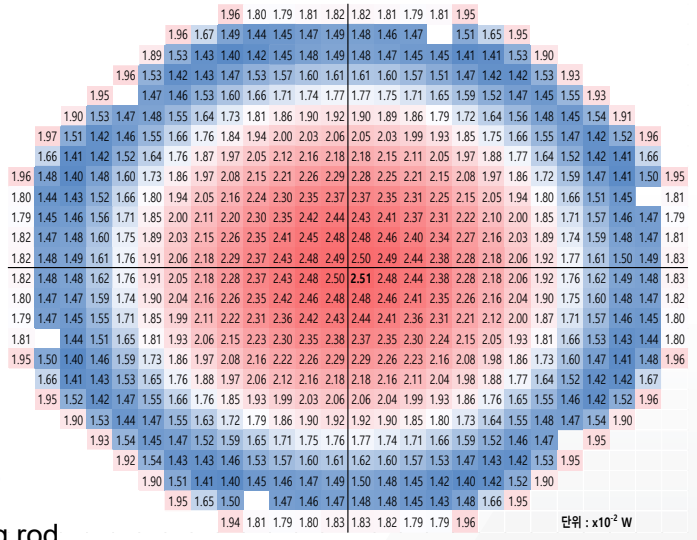
- S-core 1.74 at critical CRs position of 260 mm
- C-core 1.72 at critical CRs position of 254 mm



Power distribution of S-core



Axial power distribution of power peaking rod



Power distribution of C-core

Core Design

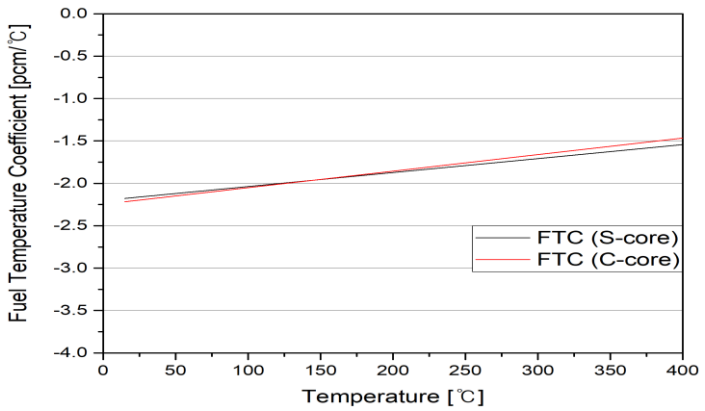
Neutronic Characteristics

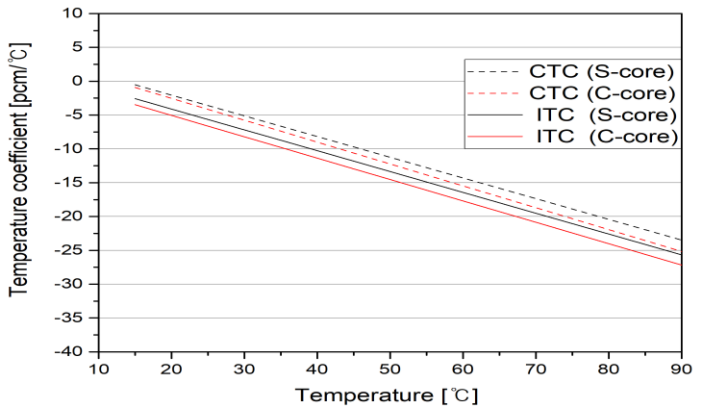
Control rods worth

Parameter	S-core (570 fuel rods)	C-core (550 fuel rods)
Excess reactivity [pcm]	440	440
Shutdown margin [pcm]	1320	1210
Integral worth of one CR [pcm]	340 ~ 350	330 ~ 340

Temperature reactivity coefficients

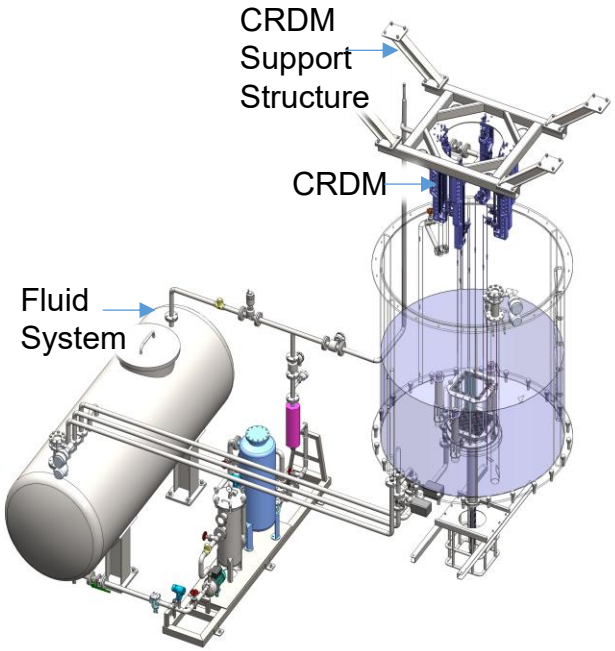
- Fuel temperature coefficient(FTC), negative for 15~400℃
- Temp. coefficient of Coolant(CTC) & Isothermal(ITC), negative for 15~90℃



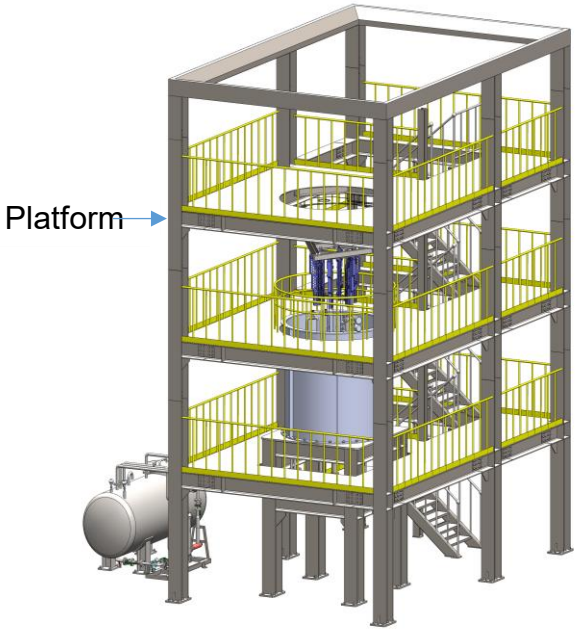


Reactor Structure Design

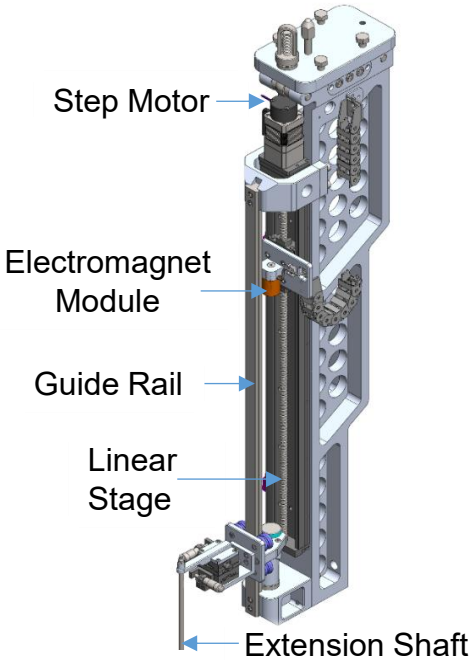
Reactor Structure & CRDM



<Interface between the reactor structure and surrounding equipment>



<Reactor structure And platform>



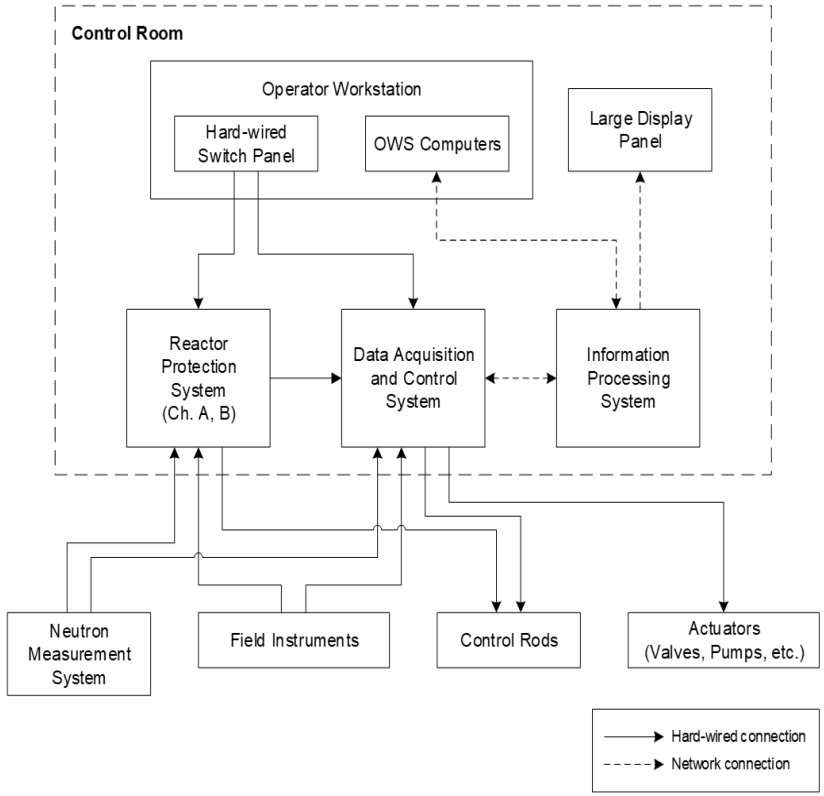
<Control Rod Drive Mechanism>

Korea Atomic Energy Research Institute

Instrumentation & Control System Design

I&C System Concept

- I&C system consists of
  - Reactor Protection System (RPS)
  - Data Acquisition & Control System (DACS)
  - Information Processing System (IPS)
  - Operator Workstation System (OWS)
  - Neutron Measurement System (NMS)
- RPS performs the automatic or manual reactor shutdown function using two independent channels.
- DA performs the reactivity regulating function by receiving neutron measurement signals and controlling the control rods.
- NMS consists of 2 channels for protection and 1 channel for regulation.



<I&C System>

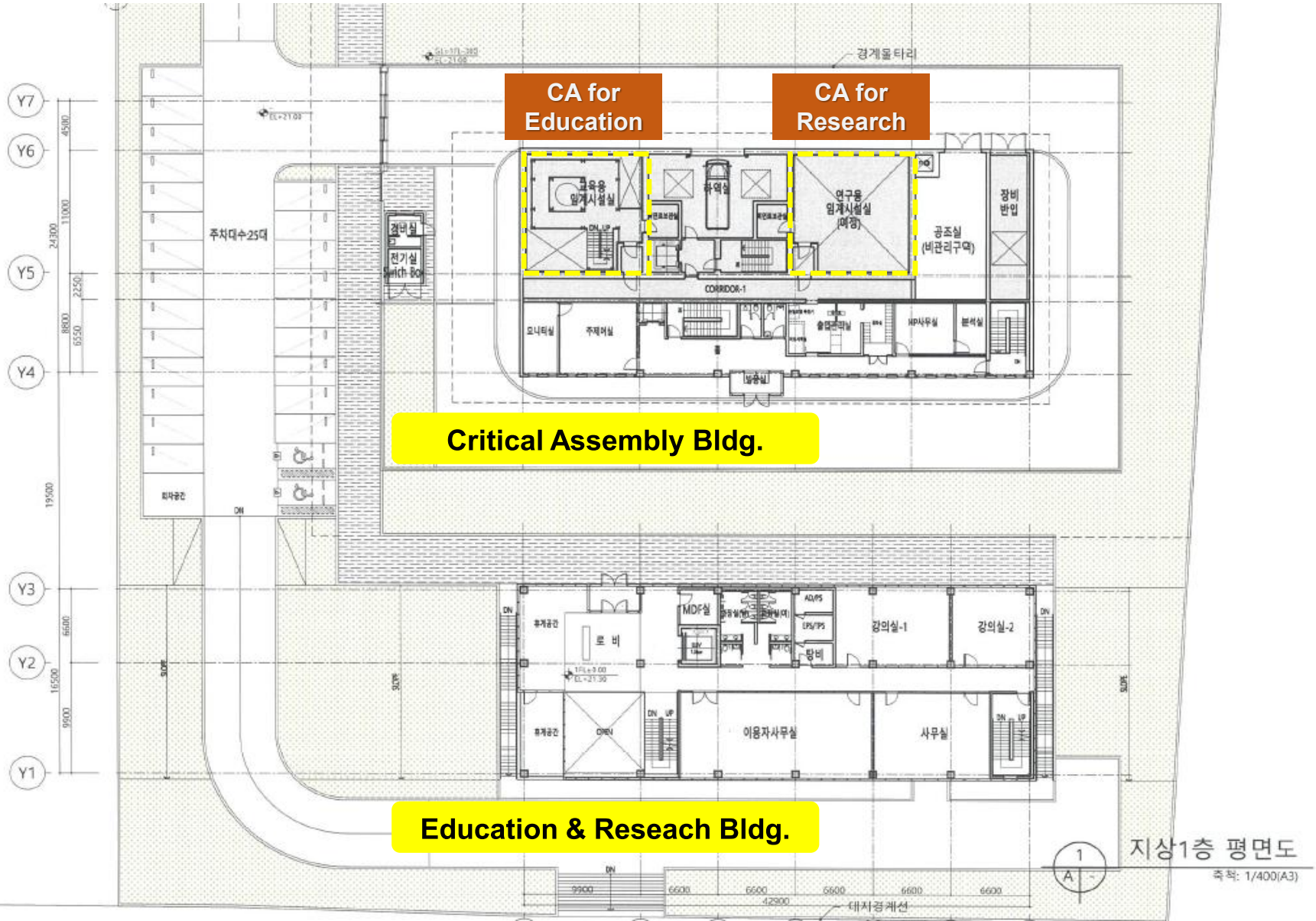
Safety Analysis

Design Basis Event

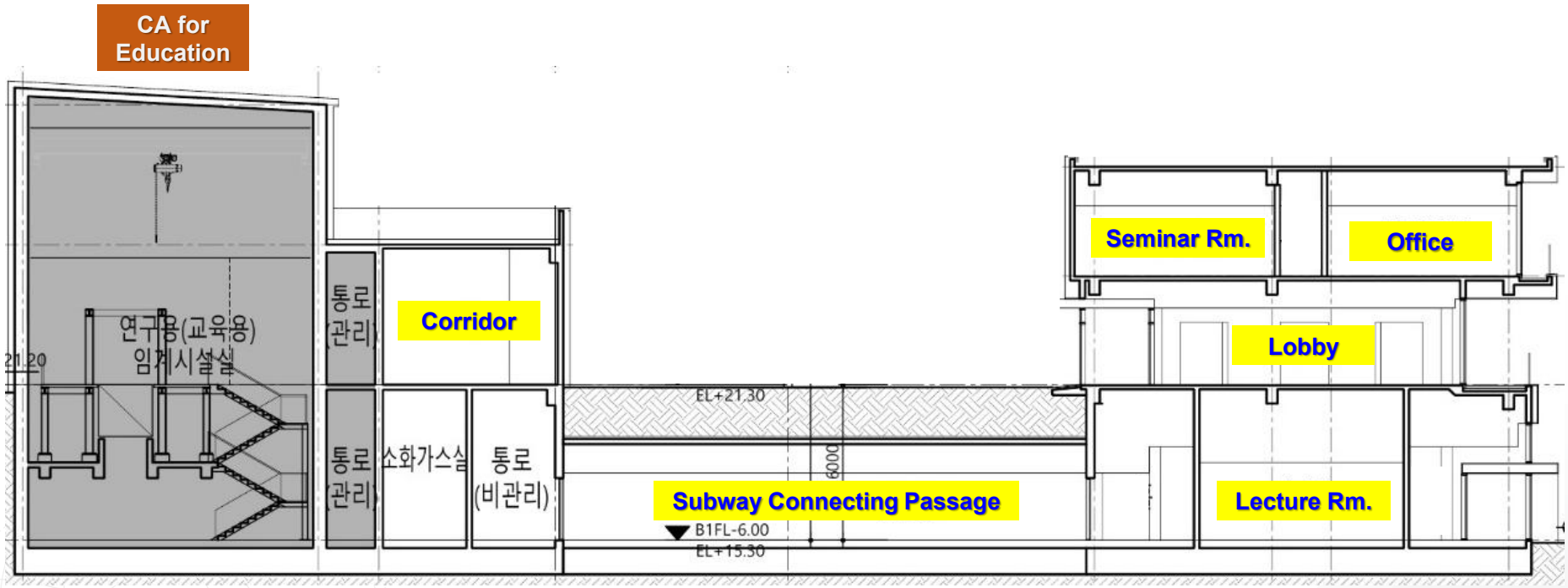
- Establishment of design basis event considering on IAEA safety standards, US SAR on non-power reactors and KINS safety assessment guidelines.

Event	Design Basis Event	Reason of Selection
Power Loss	• Normal power loss	• Control and monitor the reactor with power supplied from an external source
Excess Reactivity Insertion	• Excess reactivity insertion during full power or start-up operation	• Mechanical failures of CRDM and failures of control instrumentation or improper operation of the software
Loss of Coolant Flow	• Partial blockage of the coolant channel due to foreign material	• Foreign materials may fall onto the upper part of the fuel and partially block the fuel coolant channel
Loss of Coolant	• Loss of coolant due to vessel boundary damage	• Loss of coolant may occur due to damage to the vessel tank or piping break
Incorrect Handling and Failure of Equipment	• Carelessness in fuel handling • Fuel cladding damage • Loss of shielding	• Drop caused by carelessness in fuel handling • Cladding damage not detected during manufacturing or due to aging • Loss of shielding performance due to inappropriate opening of drain valve

General Arrangement



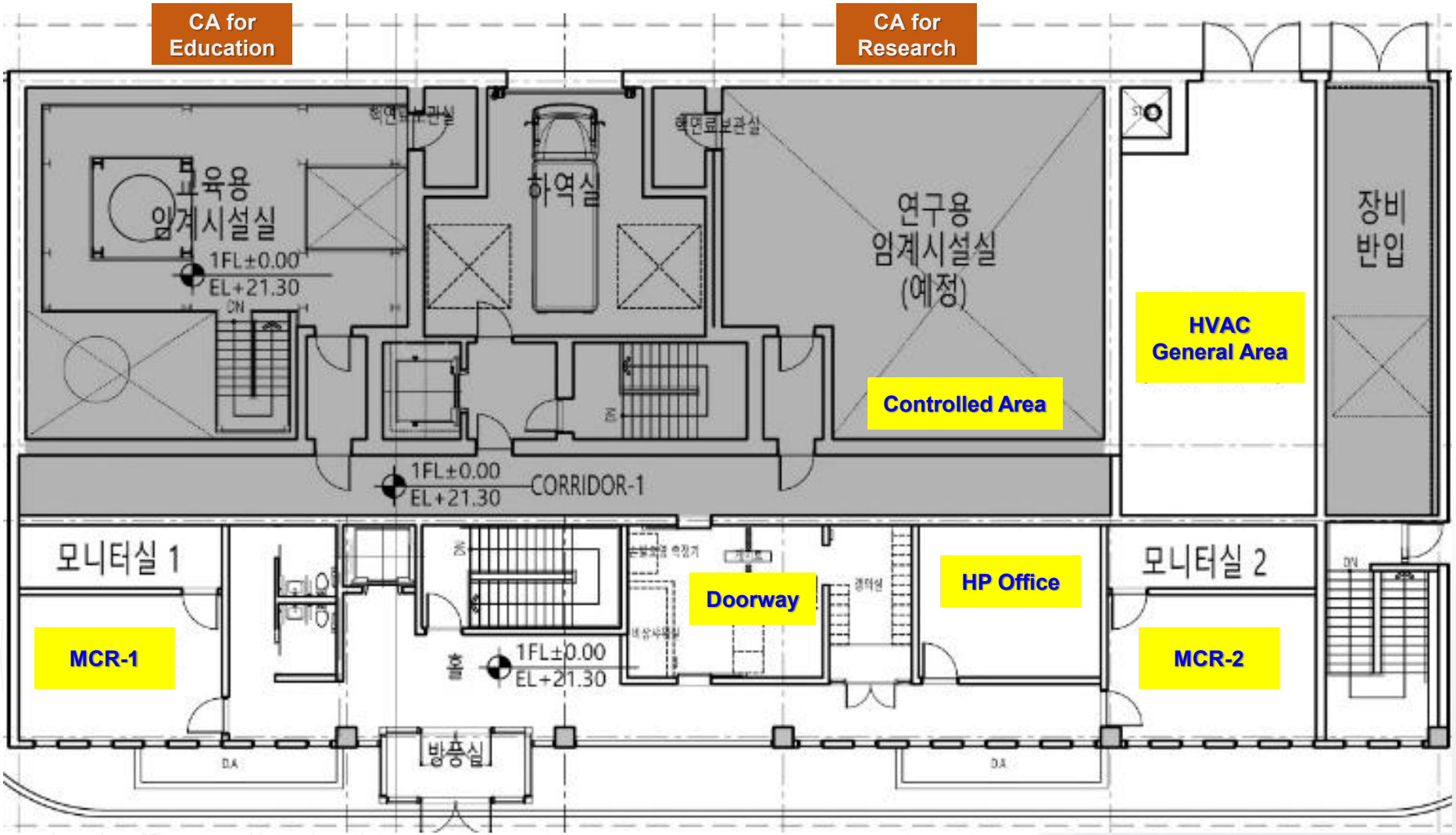
Section View



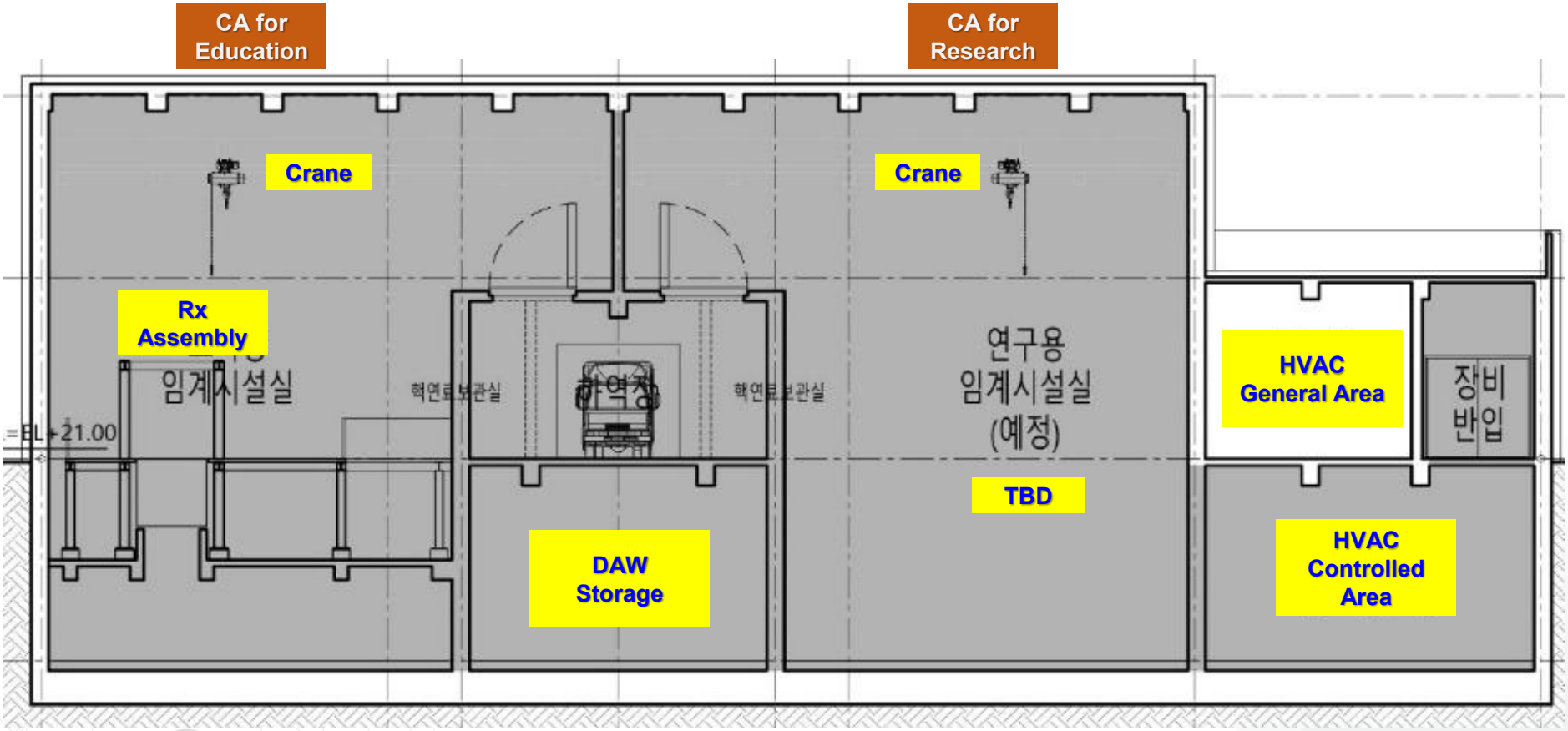
Critical Assembly Bldg.

Education & Reseach Bldg.

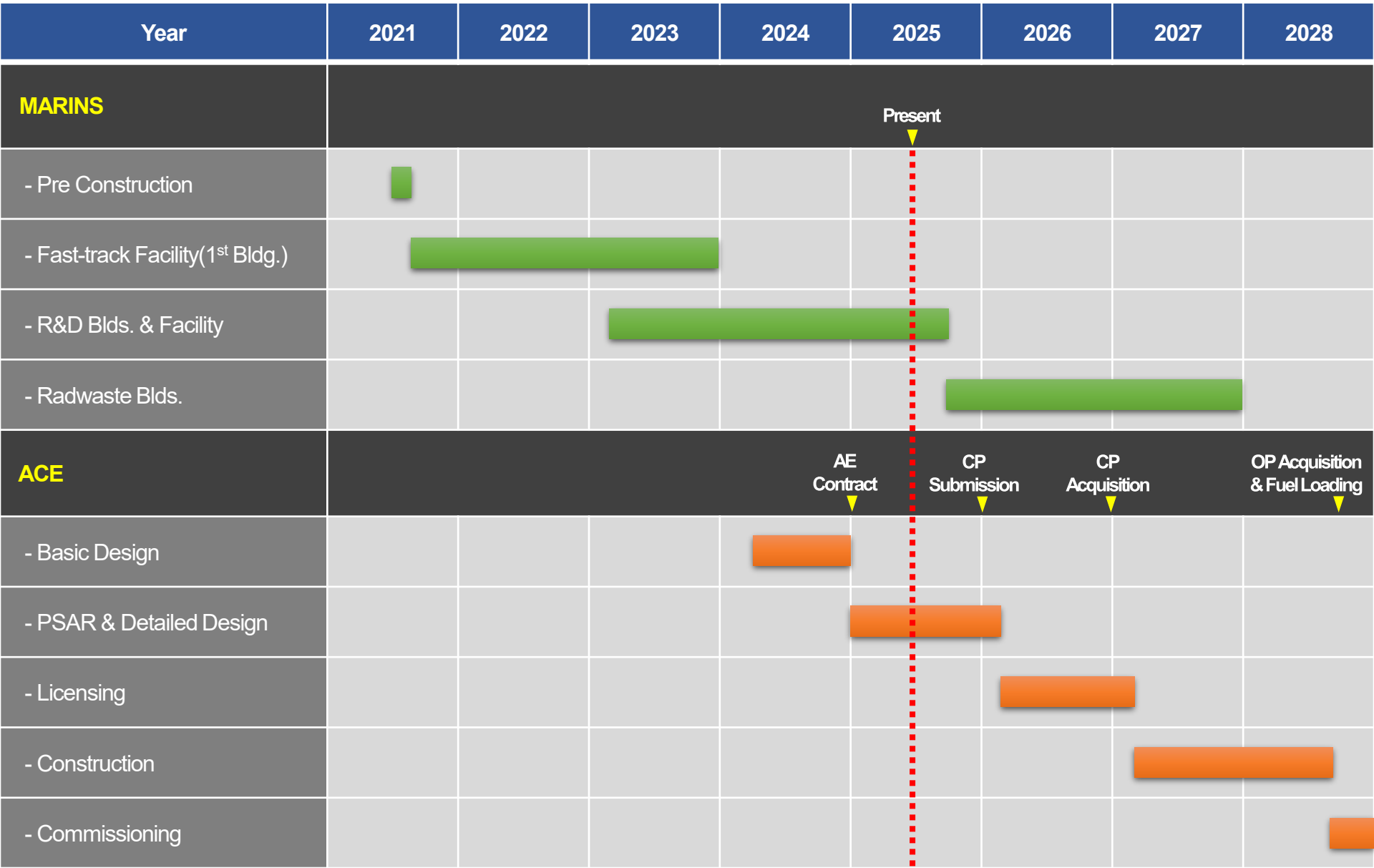
Floor Plan of Rx Building



Elevation Plan of Rx Building



Project Schedule



Expected Programs

Experiment	Measured value	Experimental method
Approach to criticality	Number of fuel rods	Loading of fuel rods (1/M method)
	Control rods position	Movement of control rods (1/M method)
Flux measurement	Flux distribution	Irradiation of activation detectors Neutron activation analysis
	Neutron spectrum unfolding	
	Geometric buckling	
Reactivity coefficient	Void coefficient	Insertion of void simulator
	Isothermal temperature coefficient	Control of pool temperature
Reactivity worth	Control rod worth	Doubling time, rod swap, rod drop
	Excess reactivity	
Neutron noise analysis	Kinetic parameter	Rossi-alpha, VTMR, PSD
Reflector effect	Infinite reflector length	Control of water level

Remarks

ACE is being designed to address limitations in existing educational reactor facilities by providing advanced reactor physics experimentation capabilities, including core reconfiguration, neutron visualization, and reactivity control.

The AGN-201K reactor at Kyung-Hee University, which has long served as a foundational platform for fundamental reactor education, will continue to play a vital role in basic training.

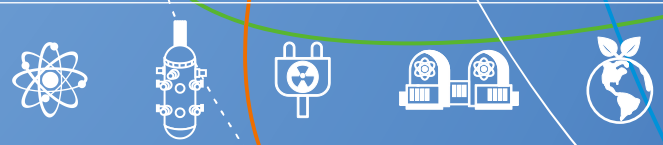
ACE is intended to complement and build upon this foundation by focusing on higher-level education and research, fostering a synergistic and tiered training system through close collaboration.

Scheduled for operation in 2029, the ACE & AGN-201K together will significantly advance South Korea’s leadership in nuclear science, education and research.

Additionally, ACE will try to be an international facility combined with HANARO and KUCA & UTR in Japan.

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

Center of Nuclear Technologies for a Better World
Acquiring People's and Global Support



Thank you for attention

KAERI Korea Atomic Energy Research Institute