

Overview of the K-DEMO Program

January 21, 2019

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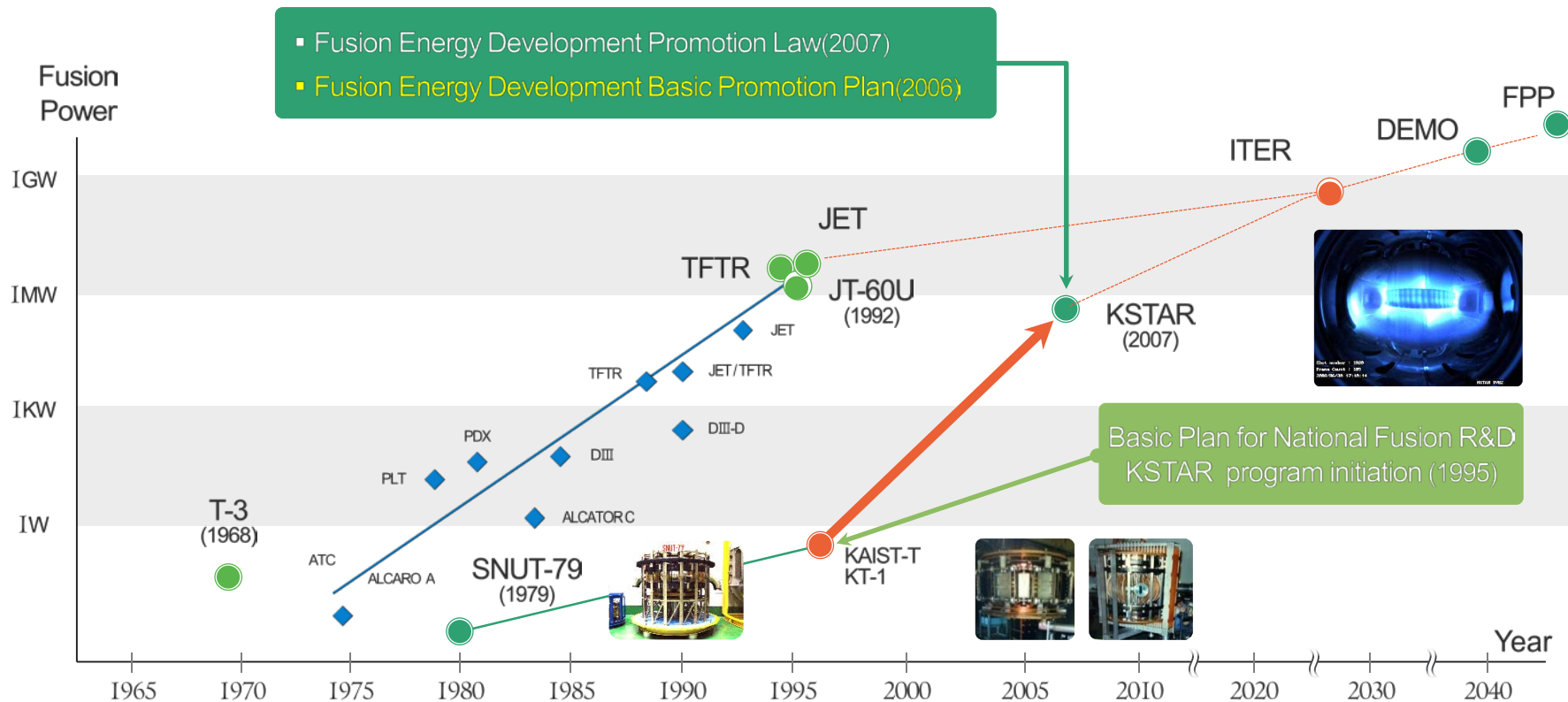
**Center for Advance Research in Fusion Reactor Engineering
Seoul National Univ.**

**10th ITER International School 2019,
January 21-25, 2019
KAIST, Daejeon, Korea**

Outline

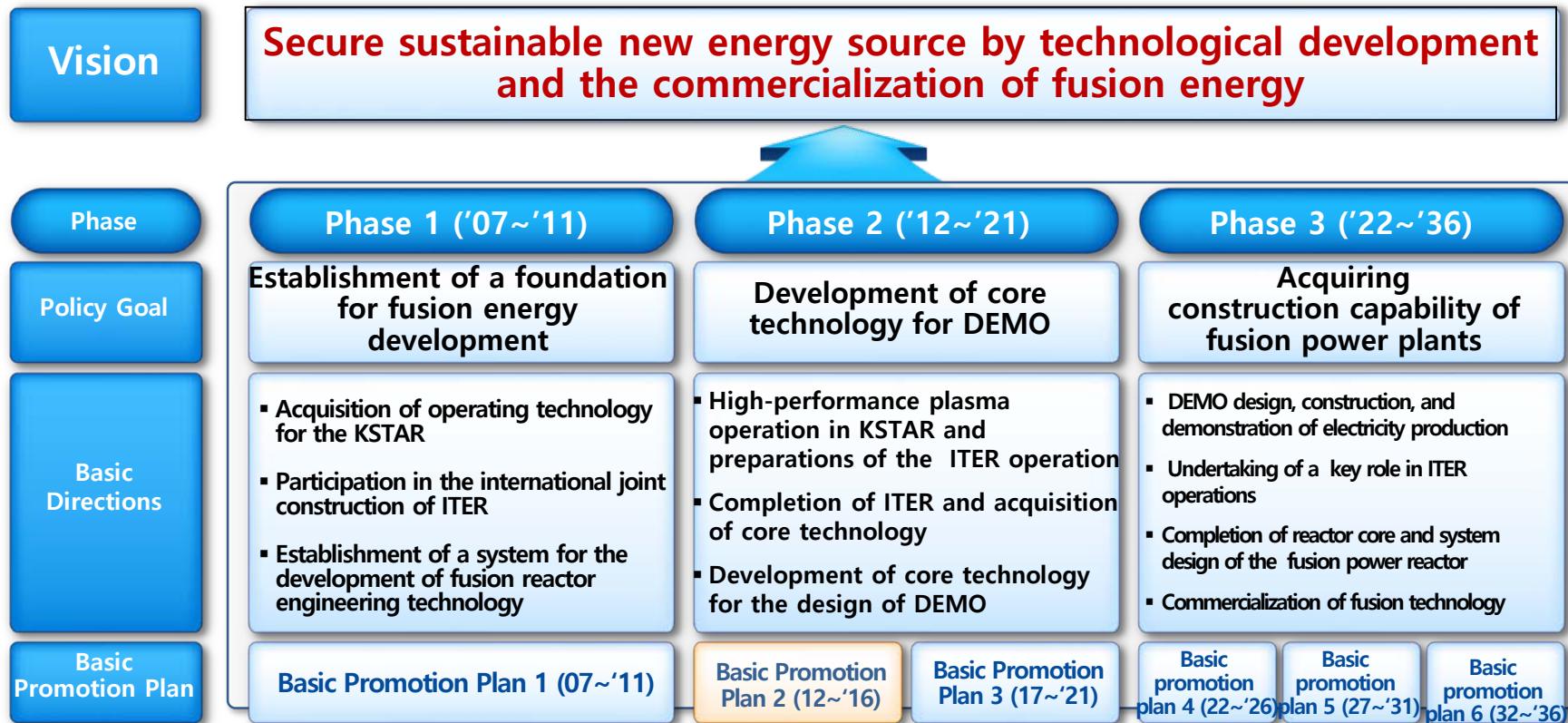
- **Korean Fusion Energy Development via Mid-Entry Strategy**
- **Korean DEMO (K-DEMO) Concept Definition**
- **DEMO Technology Development Strategy**

Korean Fusion Energy Development via Mid-Entry Strategy



KSTAR program(1995), ITER join(2003), Fusion Energy Development Promotion Law(2007), KSTAR construction(2007) leads to major role in ITER construction!

Korean Fusion Energy Development Basic Promotion Plan(2006)



Successful Fast Follower: KSTAR construction (2007) → ITER

◆ KSTAR : Strong domestic industry with global fusion network



총 69개 기업,
연인원 1,510명 참여

◆ Fostering Korean
industry and human
resources via KSTAR
→ ITER Construction



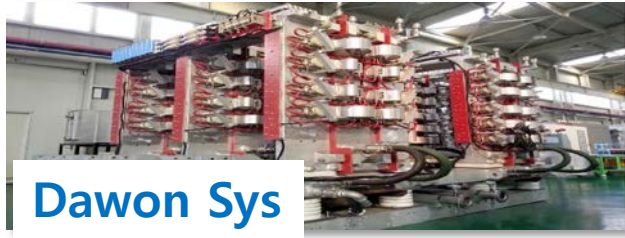
VV Port Fabrication



TF Conductor Delivery



AC/DC Converter



Successful 2nd Stage of Fusion Energy Development Plan

◆ Fostering Korean industry and human resources via KSTAR

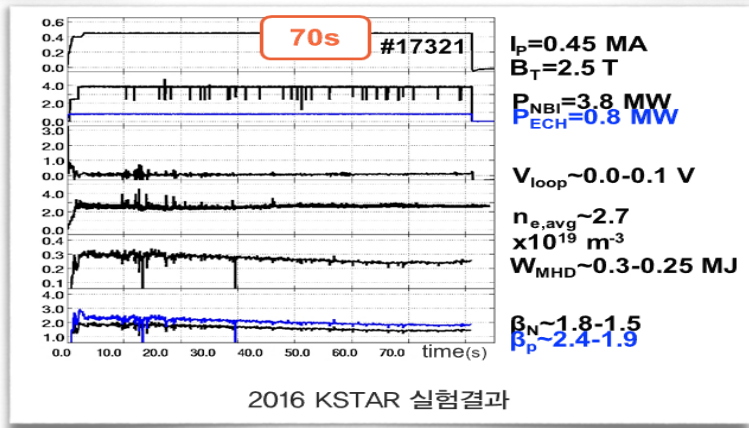
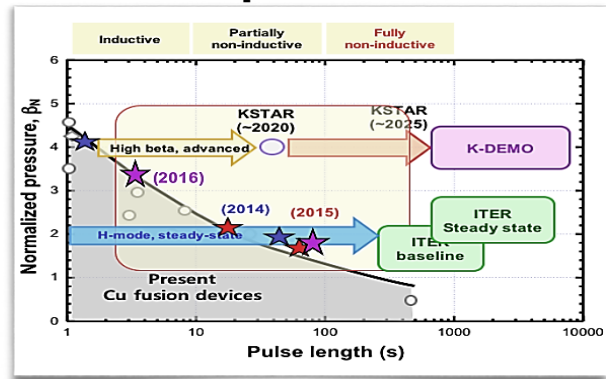


ITER Construction

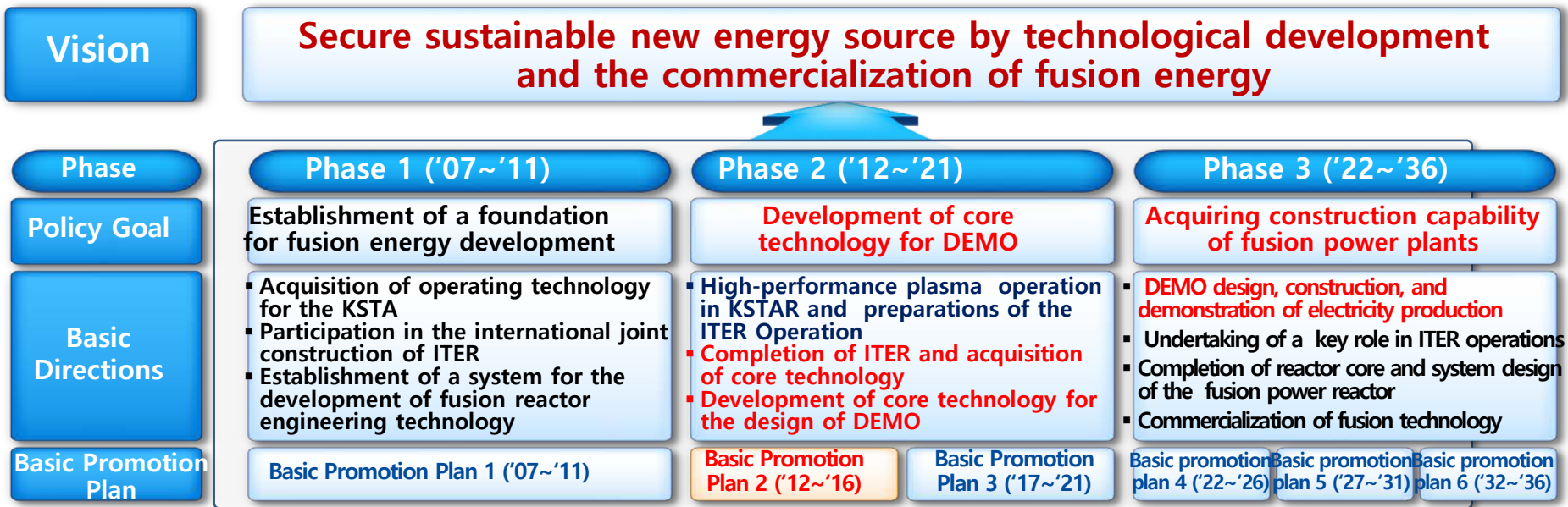
👉 TF Conductor Delivery



◆ Successful KSTAR operation



Korean Fusion Energy Development Plan and ITER Delay



ITER council confirms new first plasma date: December 2025

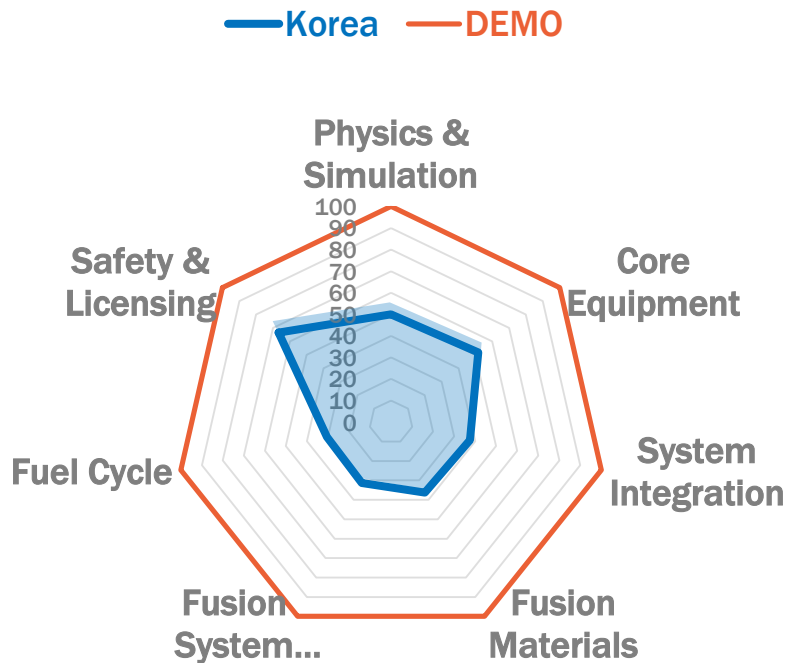
New schedule for ITER leading to first Plasma in 2025

Staged approach to lead to new ITER Baseline

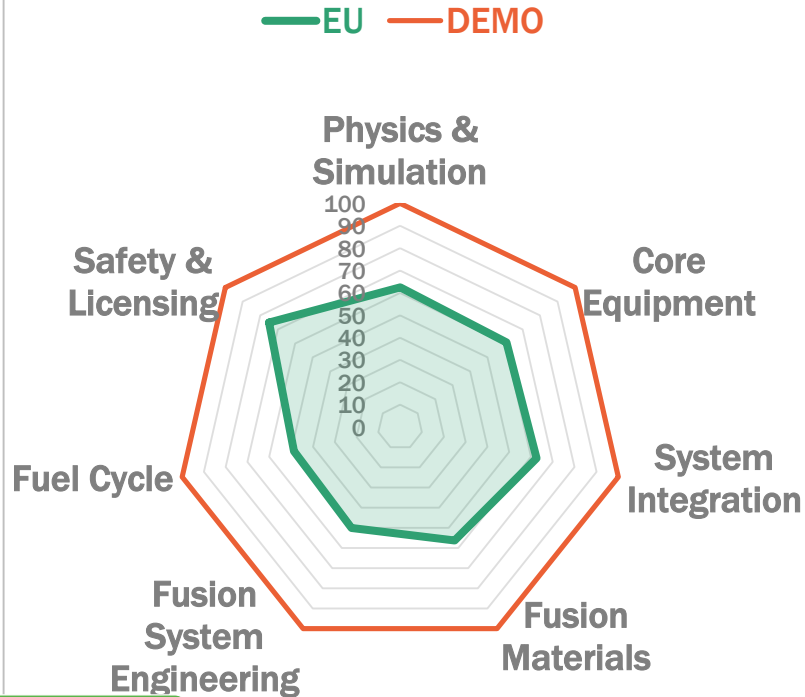
will further delay the first D-T operation until at least 2035.

Technical Readiness for DEMO

Korean Fusion Technology level



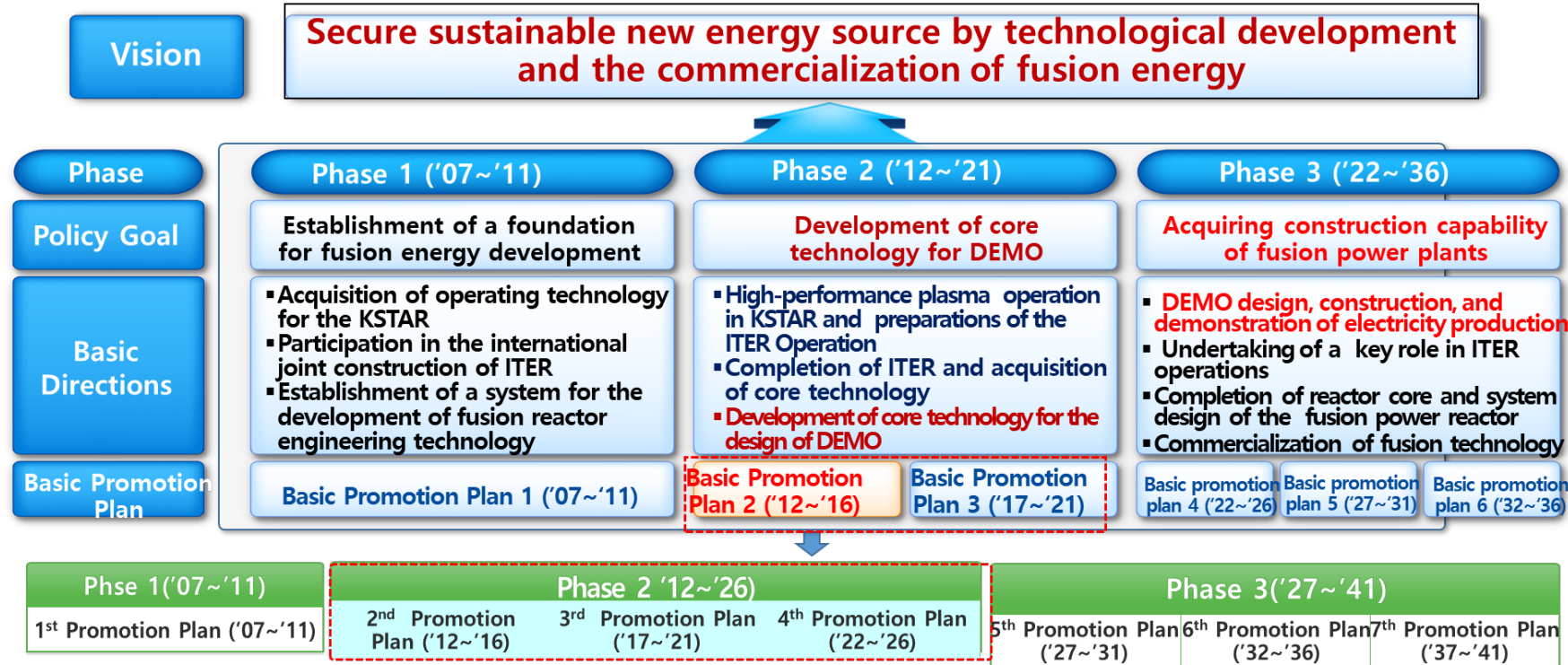
EU Fusion Technology level



Are we going to be ready for DEMO after Phase 2 ?

No! Korea is very weak in the fields of Fusion materials, Fuel cycle and Energy conversion systems !

Revised Fusion Energy Development Basic Promotion Plan (2017)



Five more years for the Phase 2 reflecting delayed ITER schedule

3rd Promotion Plan ('17 ~ '21) : "Preparation of Basis for Fusion Reactor Technology Development",

4th Promotion Plan ('22 ~ '26) : "DEMO Conceptual Design and Fusion Reactor Technology Development"

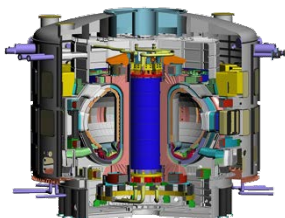
DEMO Preparation in the Revised Basic Promotion Plan (2017)

Securing DEMO preparation via KSTAR and ITER projects



- KSTAR R&D (Next-generation operation mode)
- ITER operation (Burning plasma)

▶ DEMO reactor operation technology

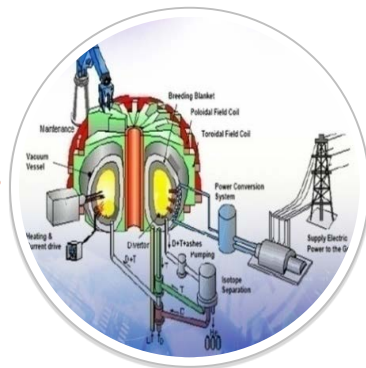


● ITER construction and core technology

- ITER construction : Technology for design, manufacturing and integration
- ITER non-procurement: Divertor and sub-system technology
- ITER TBM : Material and blanket technology

▶ Fusion reactor technology development

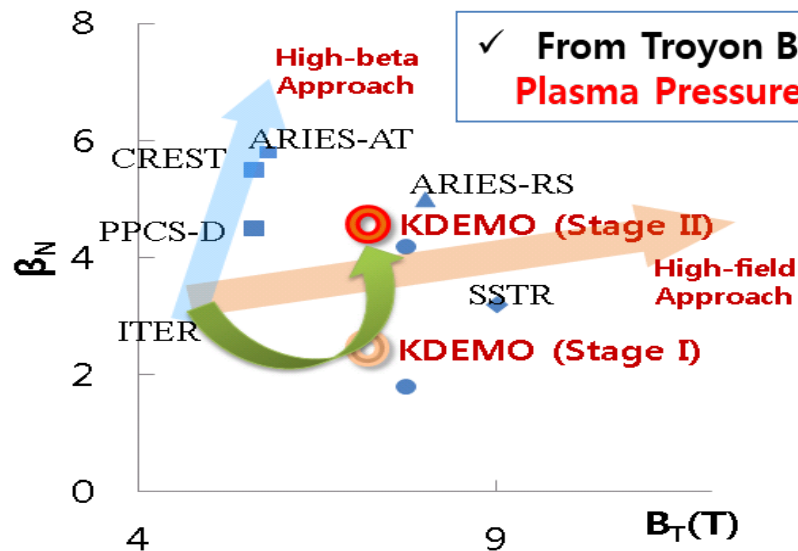
Perform
Conceptual DEMO Design



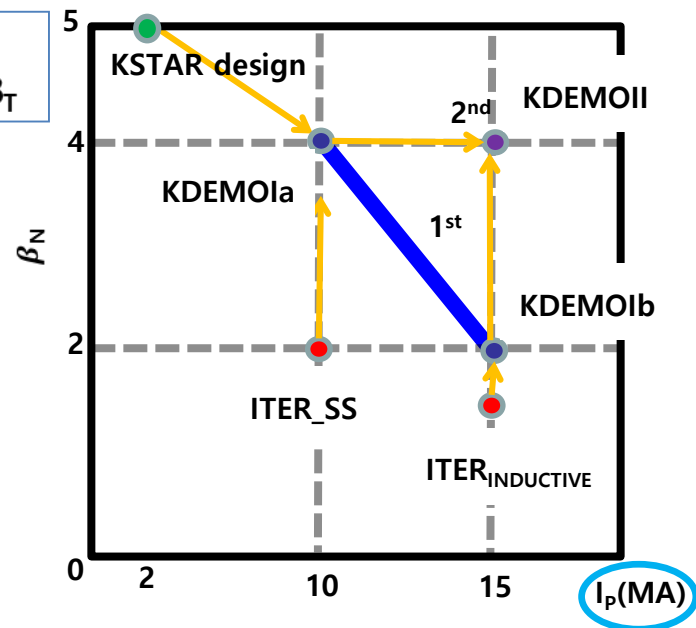
Secure
DEMO Base Technology

K-DEMO Concept Definition

Demonstrate electricity generation, tritium self-sufficiency with cost data



- Similar Size of ITER (engineering approach)
- High field approach ($B_o > 7$ T, $B_{peak} = 16$ T)
- Two stages : $2200 \text{ MW}_{th} \rightarrow 3000 \text{ MW}_{th}$
- Extrapolation from KSTAR and ITER operation



Reference design of DEMO will be continuously evolving according to the progress of fusion-related R&D while its design guides the R&D.

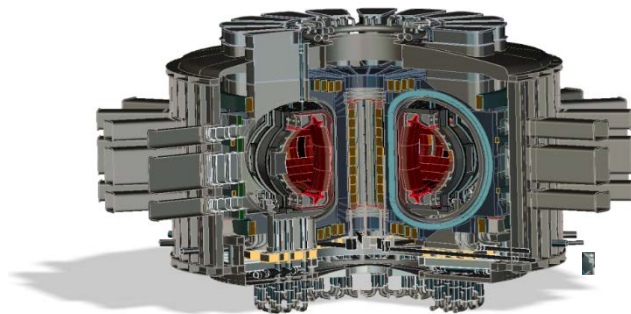
DEMO Technology Development Strategy and Roadmap (2018)

◆ Secure DEMO concept and generate approximate overall project cost

Main Parameters

$R = 6.8 \text{ m}$, $a = 2.1 \text{ m}$

B-center = 7.4 T (peak 16T)



◆ Establish DEMO roadmap with its technology development strategy

- Present ITER cost may tell order of magnitude for the DEMO plant cost
- ITER schedule is not any more ticking clock for DEMO
- Linkage of human and industrial resources from KSTAR to ITER tells that there is a critical transition time to DEMO

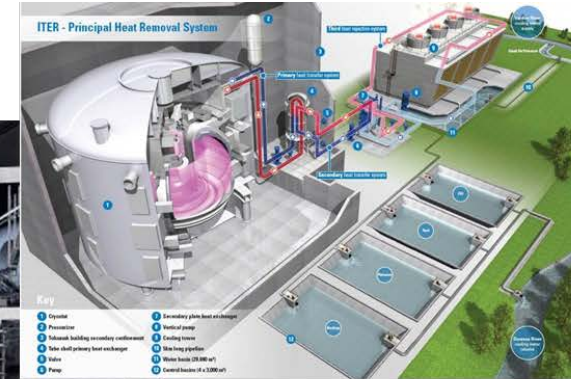
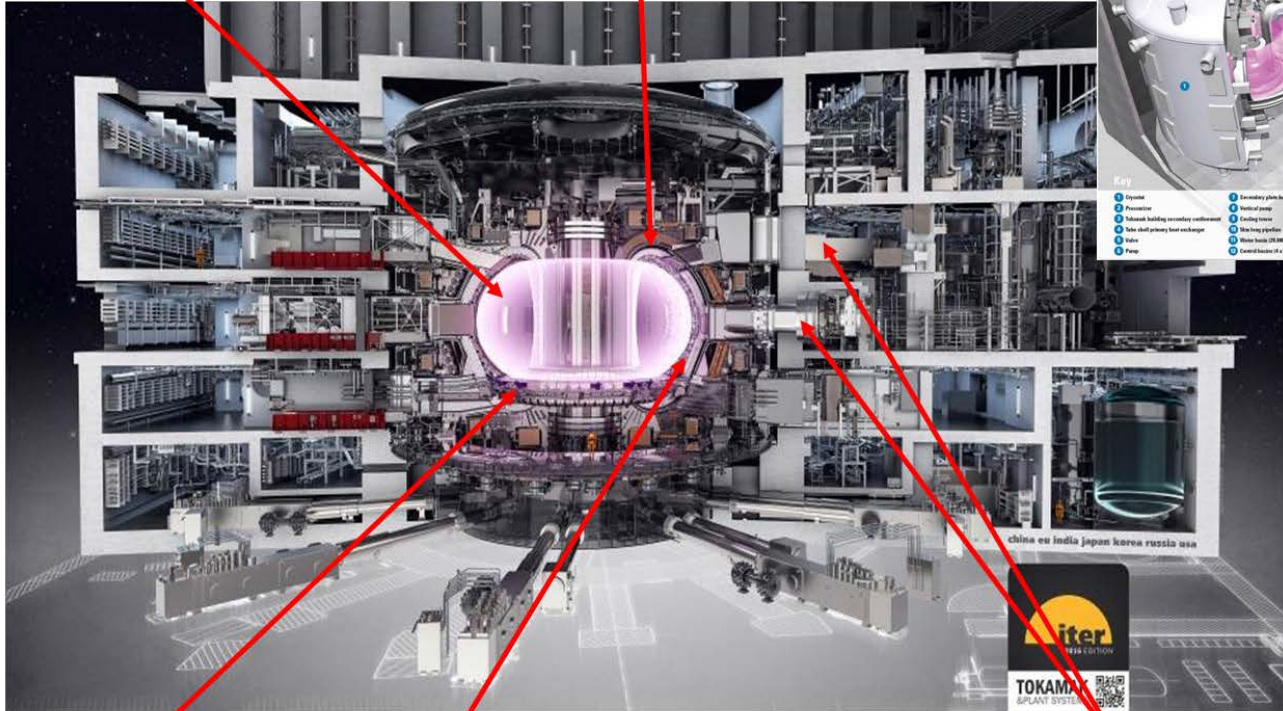


We may need some kind of Mid-Entry strategy for DEMO !

K-DEMO Realization from ITER

Plasma Performances

Superconducting Magnets



Coolant System
→ BoP

Divertor: Heat Removal

Blanket → Breeding Blanket, Heat exchange

Heating & Current Drive Systems

KSTAR R&D Plan for DEMO

Near-term Upgrade and Research Plan in KSTAR

Y.K. Oh

2008



2017



First plasma
(ECH 84 GHz)

Long-pulse H-mode
(NBI~5.5 MW)
(ECH~1 MW)

Long-pulse H-mode research

- Long pulse H-mode (>70s)
- ELM research & control (>30s)
- Alternative operation modes (ITB, low q, ..)

2017



2021



Heating upgrade
(NBI~12 MW)
(ECH~6 MW)

Advanced scenario & MHD research

- **Stable high beta operation**
($\beta_N > 3.0$, $T_{ion} \sim 10$ keV)
- **Advanced mode develop.**
(hybrid, ITB, low q)
- **MHD & disruption control**

2021



2025 ~



Divertor upgrade
(Tungsten divertor)
(Detached divertor)
(Diagnostics)

Advanced current drive
(LHCD~4 MW)
(Helicon CD~4 MW)

Steady-state & reactor mode research

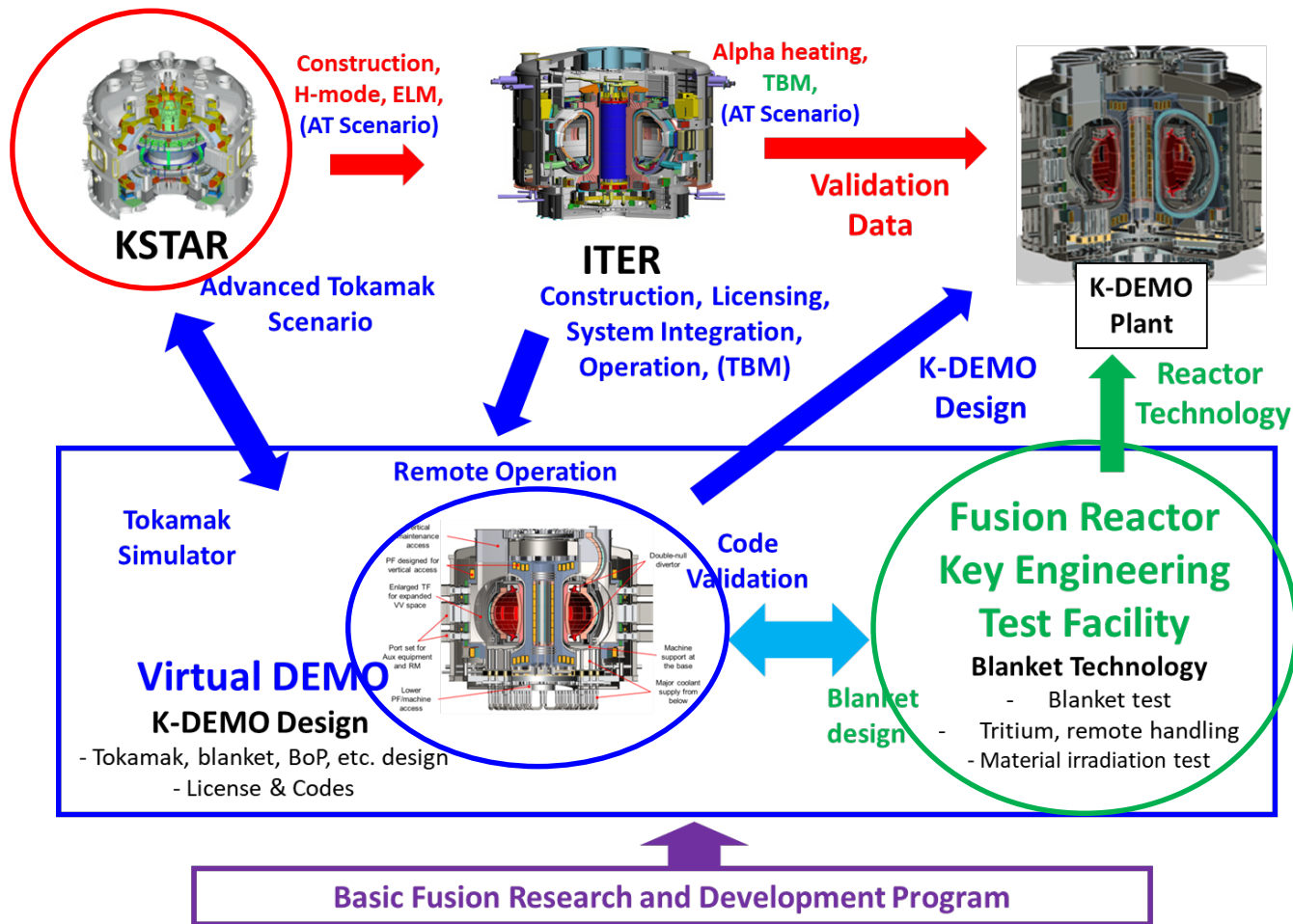
- Tungsten divertor & active cooling
- Advanced current drive under test
(HFS LHCD & Helicon CD)
- Steady-state operation (~300s)

Update DEMO Technology Development Strategy

- Core technology development plan will be pursued as a first step by concentrating on selected critical items with relevant facilities. Global fusion network and industrial infra for ITER can be utilized.
- Two options for DEMO according to the outcome of core technology development.
- ✓ Fusion power plant demonstration either in advanced small scale or full scale with an international consortium if needed.
- ✓ Simulator-based Virtual DEMO by integrating developed core technology.

Critical Facilities	Important Tasks
KSTAR	. Advanced operational scenario + CD + divertor
Virtual DEMO	. Full power plant validation, design and license tools
Superconducting Magnet	. High temperature superconducting magnets
Fusion Neutron Sources or IFMIF	. Material test facility, tritium production

First Mover (Accelerated) Path to K-DEMO via Virtual DEMO



Thank you for your attention !

K-DEMO Plant by 2040 ?



K-DEMO Design Parameters (Options)

Basic Parameter	Option I	Option II	Option III
Major Radius	6.0 m	6.8 m	7.3 m
Minor Radius	1.8 m	2.1 m	2.2 m
Elongation (k_{95})	1.8		
Magnetic Field (B_0)/Peak Field	7.4 Tesla / ~ 16 Tesla		
Divertor Type	Double Null (or Single Null)		
Bootstrap Current Fraction	~ 0.6		
Normalized beta	~ 4.0		
Plasma Current	> 10 MA	> 12 MA	> 13 MA
Total Fusion Power (Neutron)	1469 MW	2181 MW	2736 MW
Q-value	24	27	30
Total H&CD Power	140 MW	160 MW	180 MW
Thermodynamic Efficiency	0.35		
Gross Electric Power	690 MW	1009 MW	1258 MW
Recirculating Fraction	0.8	0.6	0.55
Recirculating Electric Power	553 MW	605 MW	692 MW
Net Electric Power	138 MW	403 MW	566 MW