Overview of the K-DEMO Program

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핵융합로공학 선행연구센터
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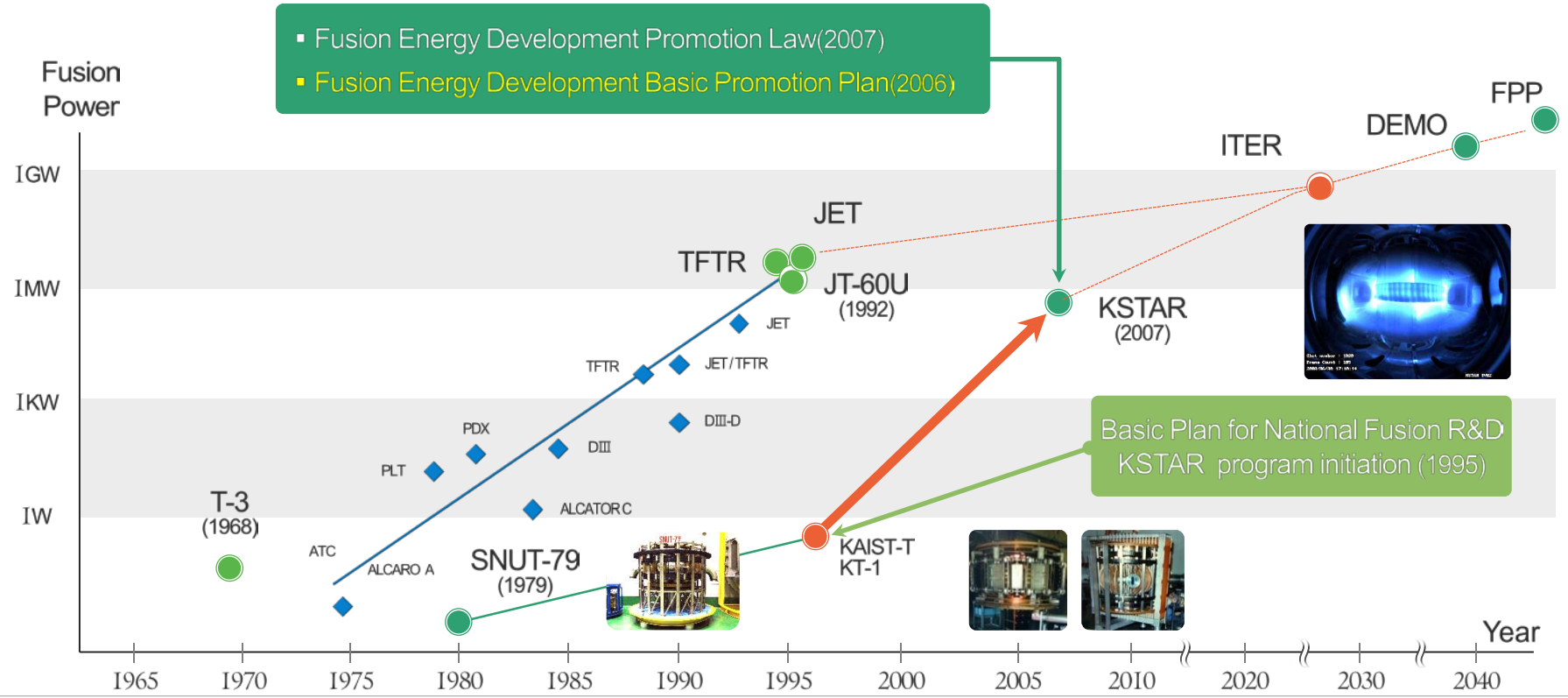
Outline

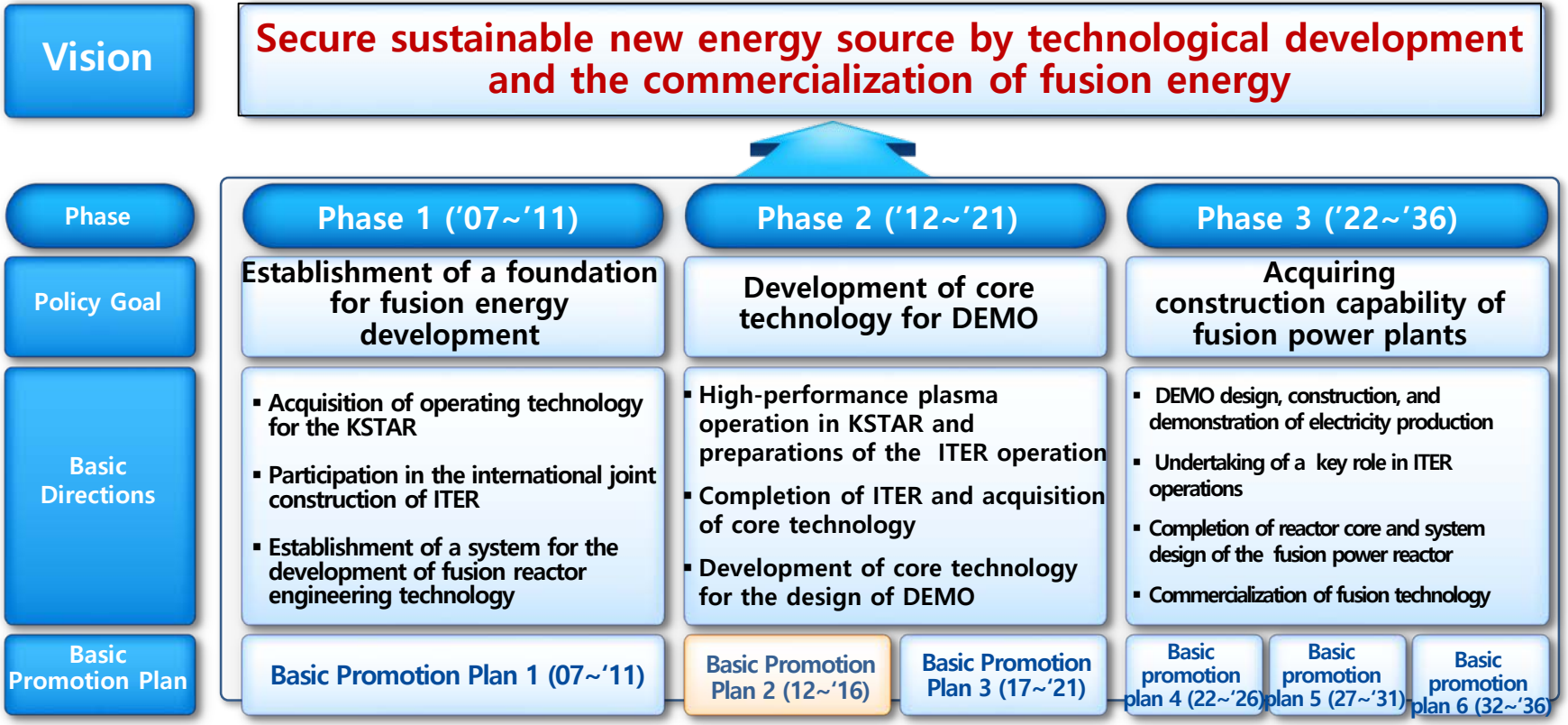
- Korean Fusion Energy Development via Mid-Entry Strategy
- Korean DEMO (K-DEMO) Concept Definition
- DEMO Technology Development Strategy

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

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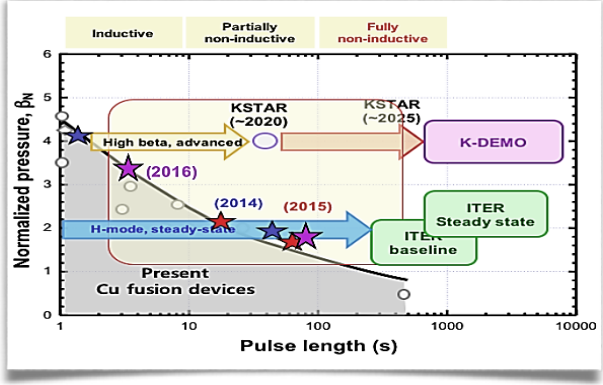
Successful 2nd Stage of Fusion Energy Development Plan

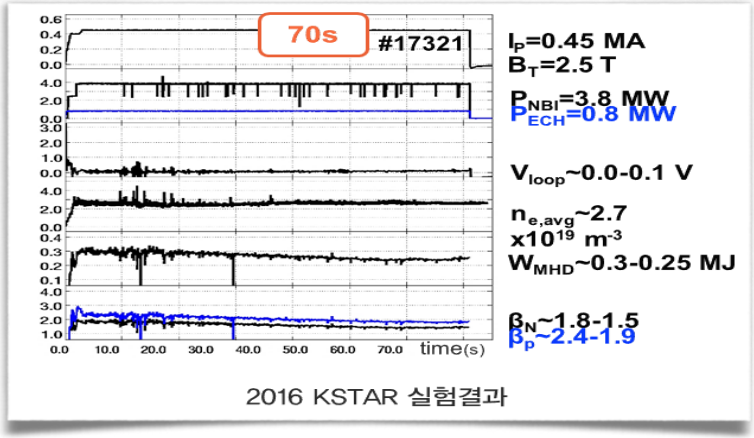
◆ Fostering Korean industry and human resources via KSTAR

➡ ITER Construction

TF Conductor Delivery

◆ Successful KSTAR operation





2016 KSTAR 실험결과

Korean Fusion Energy Development Plan and ITER Delay

Vision

Secure sustainable new energy source by technological development and the commercialization of fusion energy

Phase	Phase 1 ('07~'11)	Phase 2 ('12~'21)	Phase 3 ('22~'36)
Policy Goal	Establishment of a foundation for fusion energy development	Development of core technology for DEMO	Acquiring construction capability of fusion power plants
Basic Directions	▪ Acquisition of operating technology for the KSTA ▪ Participation in the international joint construction of ITER ▪ Establishment of a system for the development of fusion reactor engineering technology	▪ High-performance plasma operation in KSTAR and preparations of the ITER Operation ▪ Completion of ITER and acquisition of core technology ▪ Development of core technology for the design of DEMO	▪ DEMO design, construction, and demonstration of electricity production ▪ Undertaking of a key role in ITER operations ▪ Completion of reactor core and system design of the fusion power reactor ▪ Commercialization of fusion technology
Basic Promotion Plan	Basic Promotion Plan 1 ('07~'11)	Basic Promotion Plan 2 ('12~'16) / Basic Promotion Plan 3 ('17~'21)	Basic promotion plan 4 ('22~'26) / Basic promotion plan 5 ('27~'31) / Basic promotion plan 6 ('32~'36)

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.

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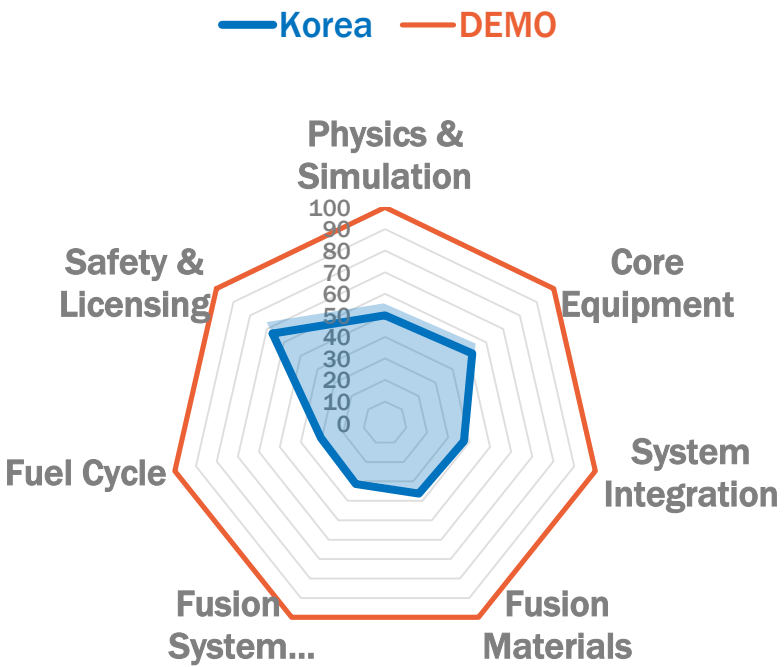
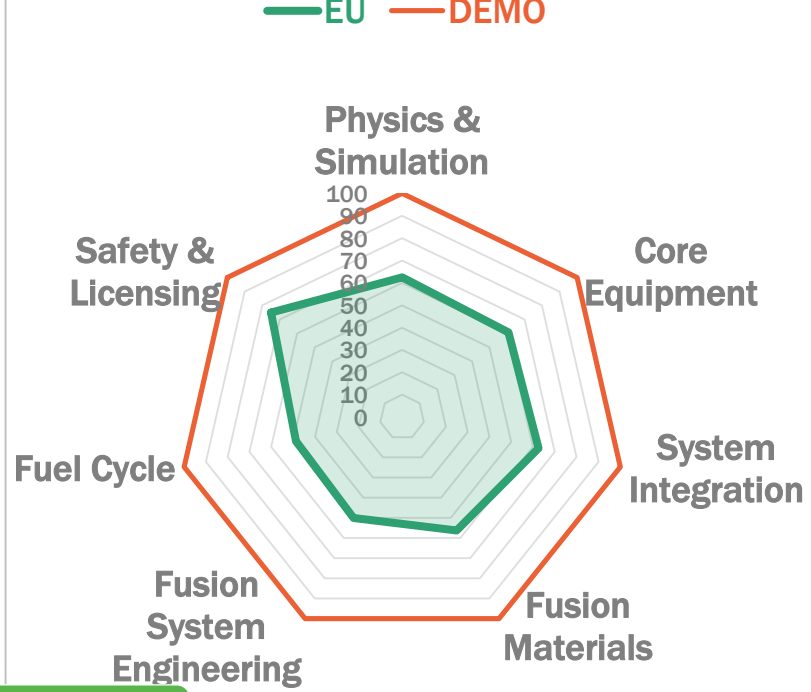
Technical Readiness for DEMO

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)

Vision: Secure sustainable new energy source by technological development and the commercialization of fusion energy

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Phse 1('07~'11)	Phase 2 '12~'26)			Phase 3('27~'41)		
1st Promotion Plan ('07~'11)	2nd Promotion Plan ('12~'16)	3rd Promotion Plan ('17~'21)	4th Promotion Plan ('22~'26)	5th Promotion Plan ('27~'31)	6th Promotion Plan ('32~'36)	7th Promotion Plan ('37~'41)

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"

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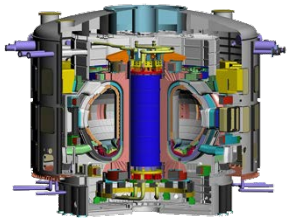
DEMO Preparation in the Revised Basic Promotion Plan (2017)

Securing DEMO preparation via KSTAR and ITER projects

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

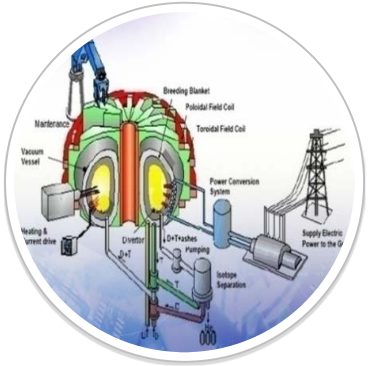
▶ DEMO reactor operation technology



- 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

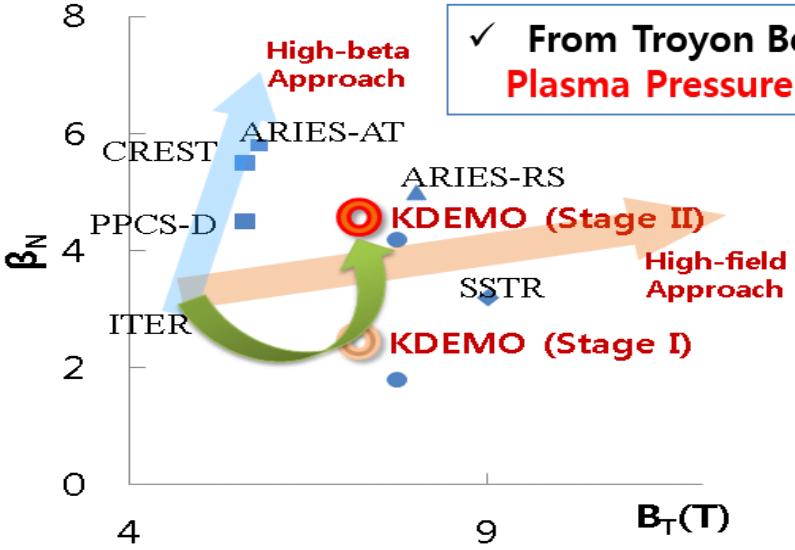
Perform
Conceptual DEMO Design



Secure
DEMO Base Technology

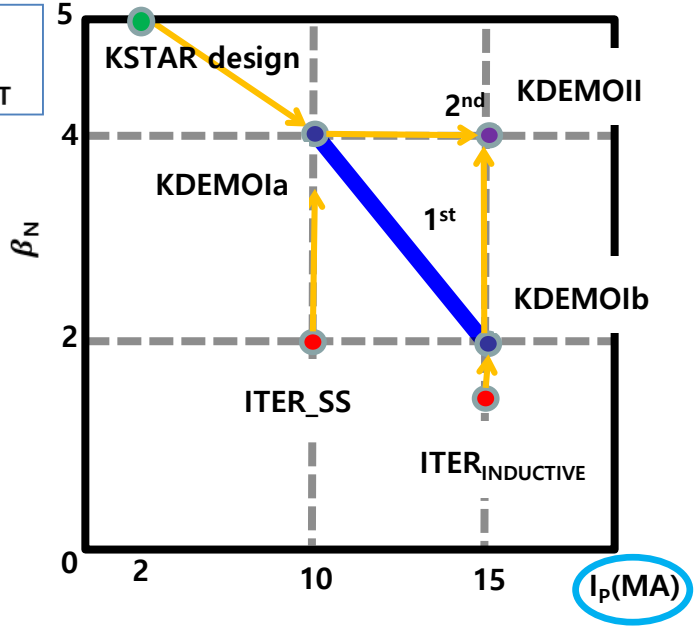
K-DEMO Concept Definition

Demonstrate electricity generation, tritium self-sufficiency with cost data



✓ From Troyon Beta Limit

Plasma Pressure Limit $\propto \beta_N I_P B_T$



- Similar Size of ITER (engineering approach)
- High field approach (B_o>7T, B_{peak}=16T)
- Two stages : 2200 MW_{th} → 3000MW_{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.

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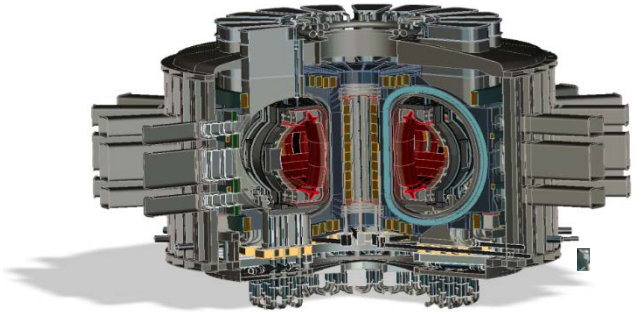
DEMO Technology Development Strategy and Roadmap (2018)

◆ **Secure DEMO concept and generate approximate overall project cost**

Main Parameters
R = 6.8 m, a = 2.1 m
B-center = 7.4 T (peak 16T)



◆ **Establish DEMO roadmap with its technology development strategy**

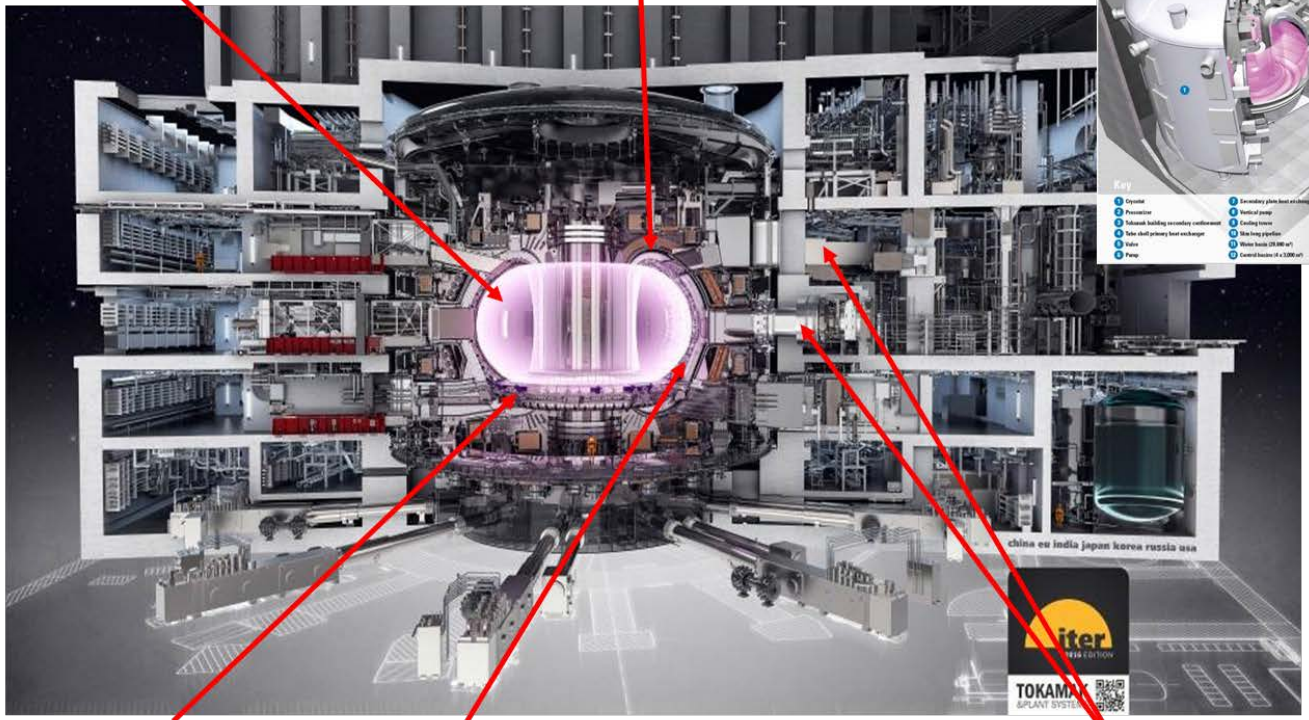
- **Present ITER cost may tell order of magnitude for the DEMO plant cost**
- **ITER schedule is not any more ticking clock for DEMO**
- **Linkage of human and industrial resources from KSTAR to ITER tells that there is a critical transition time to DEMO**

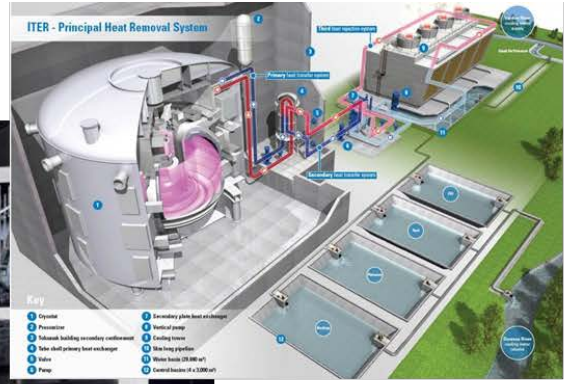
We may need some kind of Mid-Entry strategy for DEMO !

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

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, ..)*

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

Advanced scenario & MHD research
- *Stable high beta operation*
  (β_N>3.0, T_{ion} ~ 10 keV)
- *Advanced mode develop.*
  (hybrid, ITB, low q)
- *MHD & disruption control*

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)*

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Update DEMO Technology Development Strategy

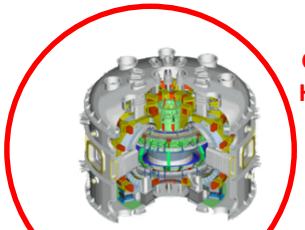
- Core technology development plan will be pursued as a first step by concentrating on selected critical items with relevant facilities. Global fusion network and industrial infra for ITER can be utilized.
- Two options for DEMO according to the outcome of core technology development.

✓ 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.

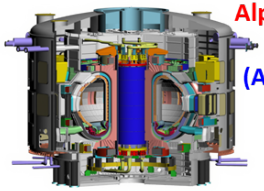
Critical Facilities	Important Tasks
KSTAR	. Advanced operational scenario + CD + divertor
Virtual DEMO	. Full power plant validation, design and license tools
Superconducting Magnet	. High temperature superconducting magnets
Fusion Neutron Sources or IFMIF	. Material test facility, tritium production

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



KSTAR

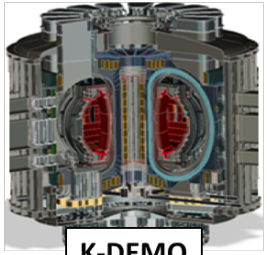
Construction, H-mode, ELM, (AT Scenario)



ITER

Alpha heating, TBM, (AT Scenario)

Validation Data



K-DEMO Plant

Advanced Tokamak Scenario

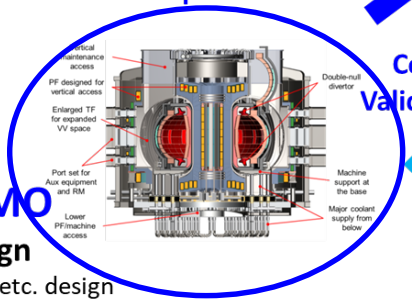
Construction, Licensing, System Integration, Operation, (TBM)

K-DEMO Design

Reactor Technology

Remote Operation

Tokamak Simulator



Code Validation

Virtual DEMO

K-DEMO Design

- Tokamak, blanket, BoP, etc. design
- License & Codes

Blanket design

Fusion Reactor Key Engineering Test Facility

Blanket Technology

- Blanket test
- Tritium, remote handling
- Material irradiation test

Basic Fusion Research and Development Program

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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_o)/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