# Status and Plan for Fusion Research in Korea

*Gyung-Su Lee*

*National Fusion Research Institute, Republic of Korea*

NFRI 국가핵융합연구소
National Fusion Research Institute

# OUTLINE

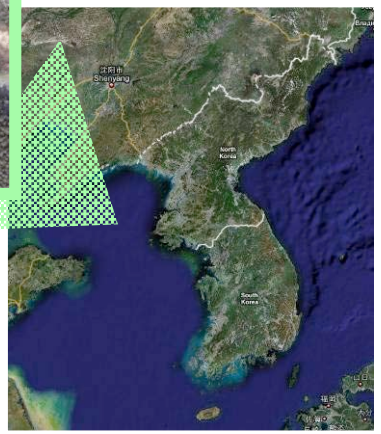

History of
Korean Fusion
Program

# National Fusion Research Institute (NFRI)
# - Foundation for the Korean Fusion Program

KSTAR Building

NFRI Campus

Daejeon, Korea

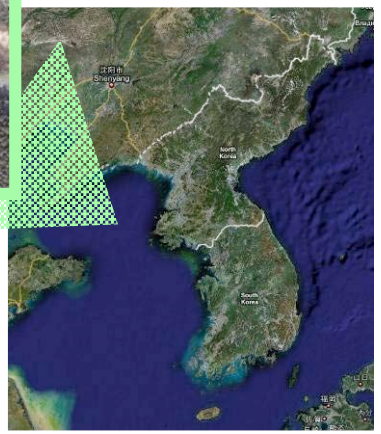


# National Fusion Research Institute (NFRI)
# - Foundation for the Korean Fusion Program

KSTAR Building

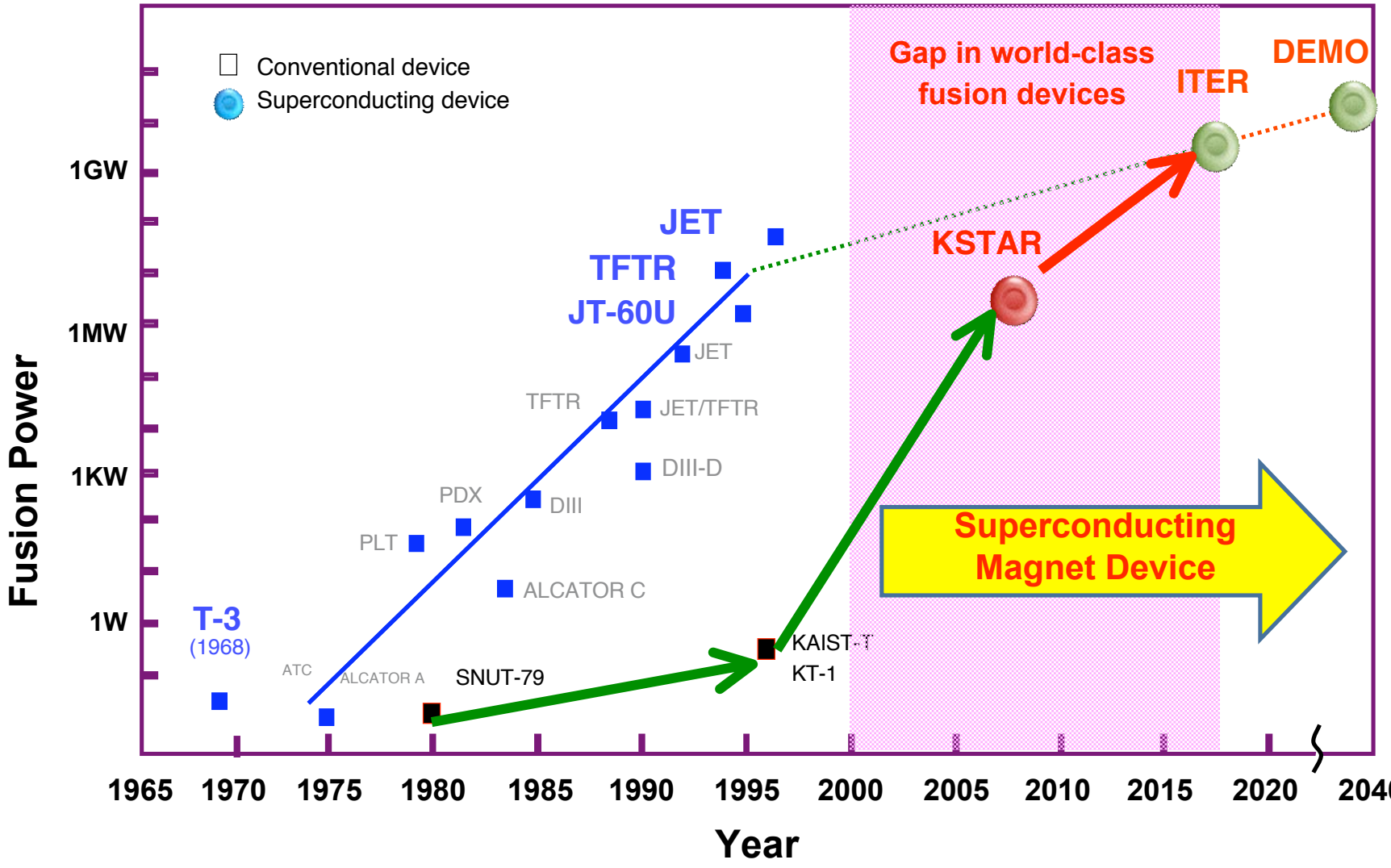
NFRI Campus

Daejeon, Korea



*Geobuk-seon (Turtle Ship)*
*First iron-clad battle ship*
*in the worlds (1592)*

# Mid-entry Strategy to lead World Fusion Research



# Launch National Fusion Project, KSTAR (Dec. 1995)

國家 核融合 研究開發 基本計劃

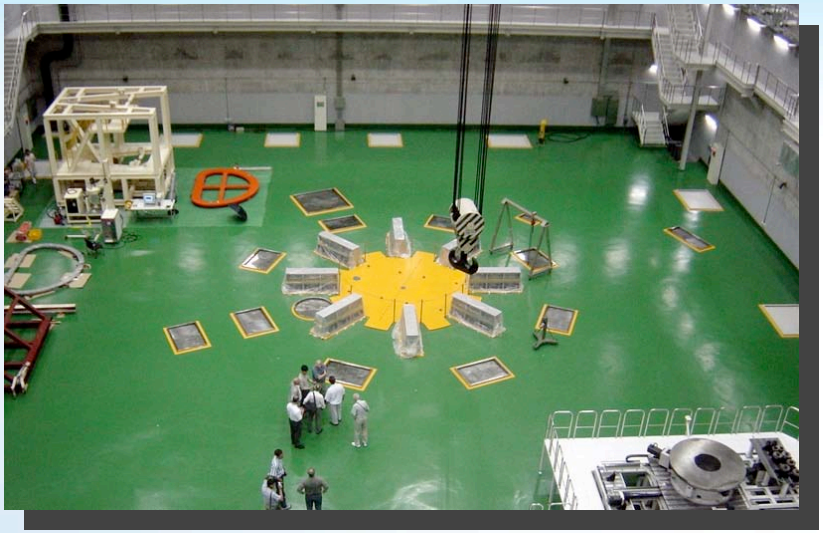
'95. 12

科學技術處

# International Reviews on KSTAR (Dec. 1997)


# Construction Start of the KSTAR Building (Dec. 1998)

# Completion of the KSTAR Building (Sept. 2002)

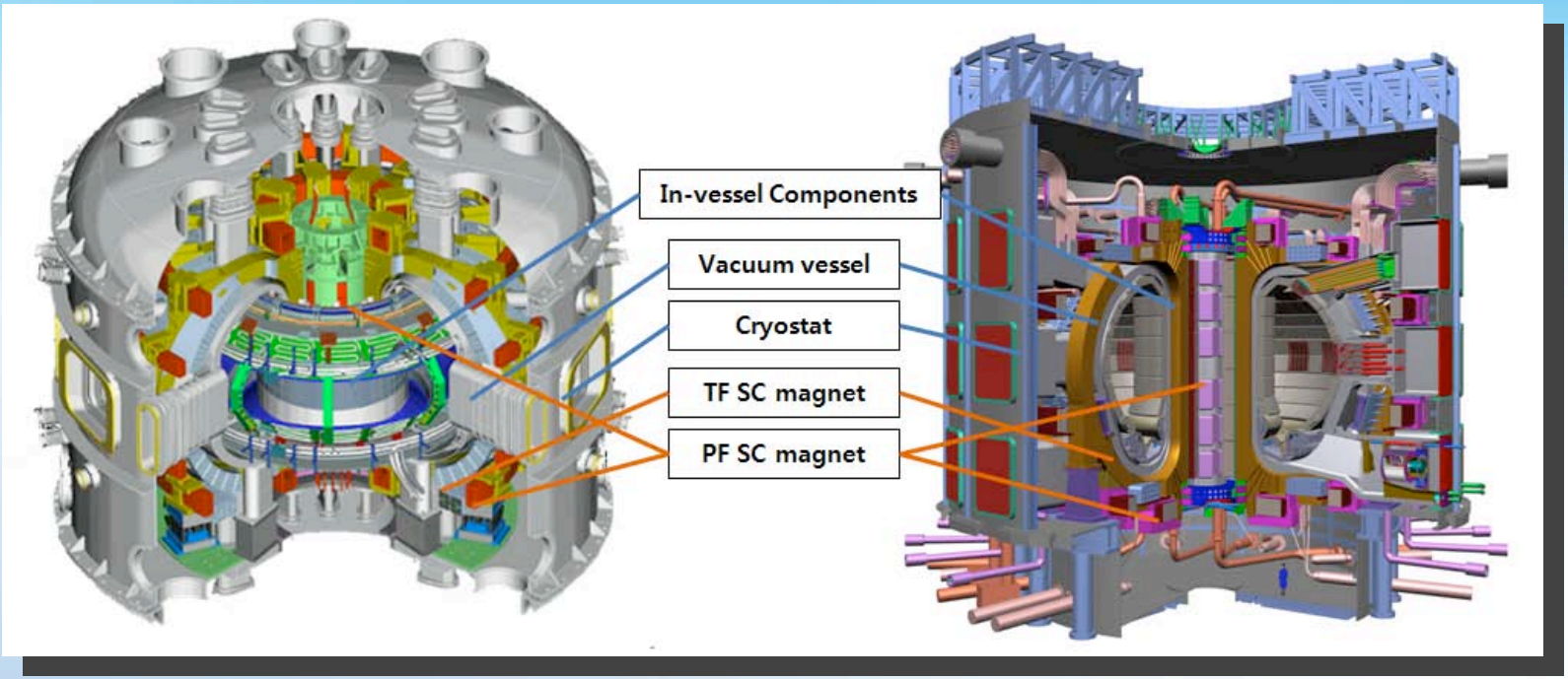



KSTAR
Program

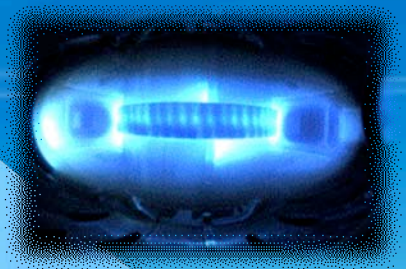
# KSTAR Mission

**KSTAR : Korea Superconducting Tokamak Advanced Research**

- To achieve the superconducting tokamak construction experience
- To develop high performance steady-state operation physics an d technology that is essential for fusion reactor development



# Technology evolution in entire process of KSTAR from concept design to the construction



June 2008
First Plasma

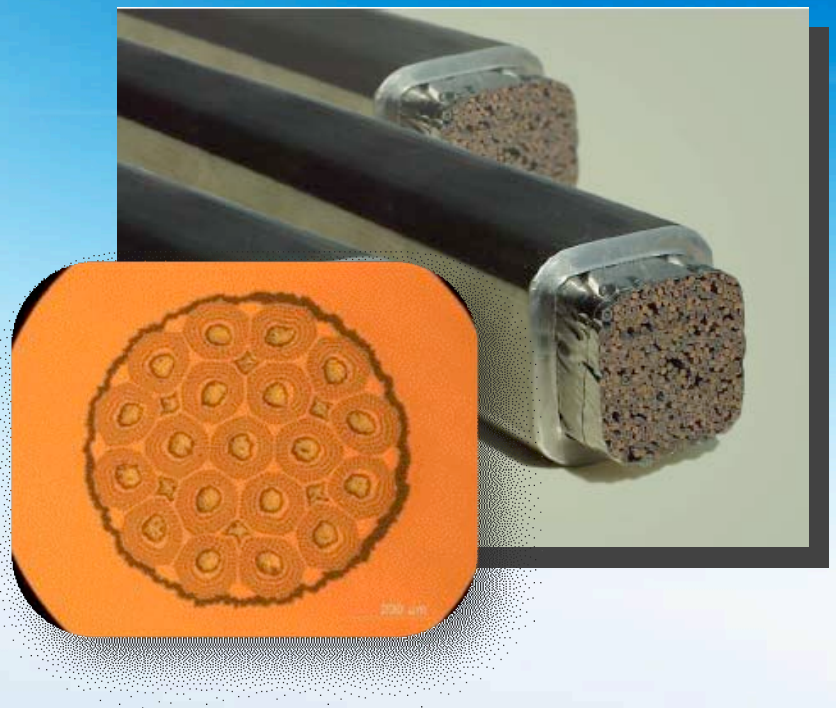
2002 - 2007
Construction of KSTAR

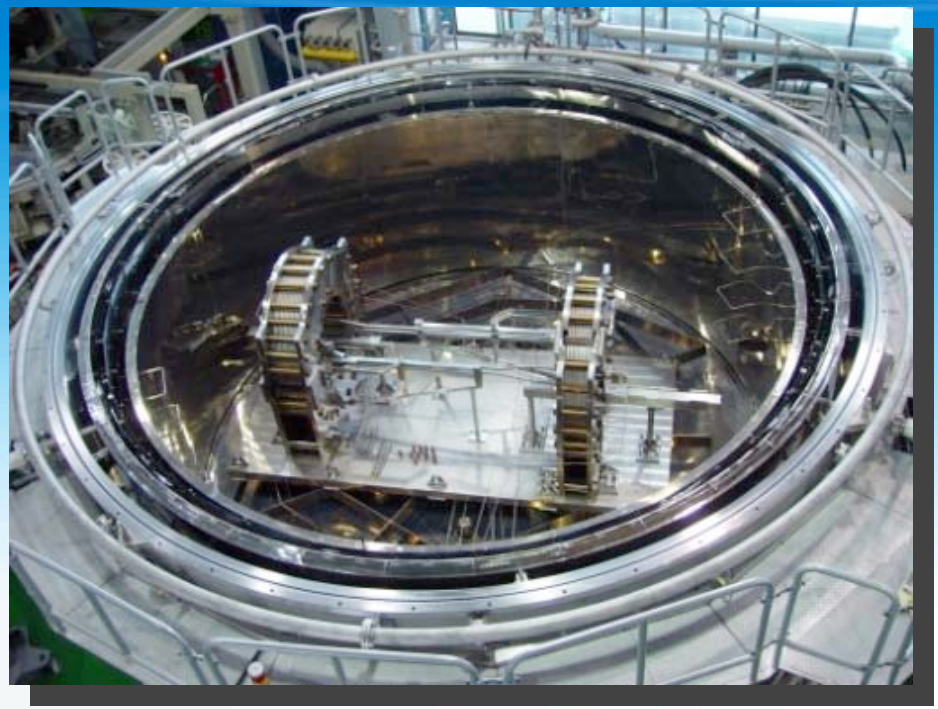
1998 - 2001
Engineering Design
and Facility Construction

1996 - 1997
Basic Design and R&D

1995
Launch of KSTAR Project

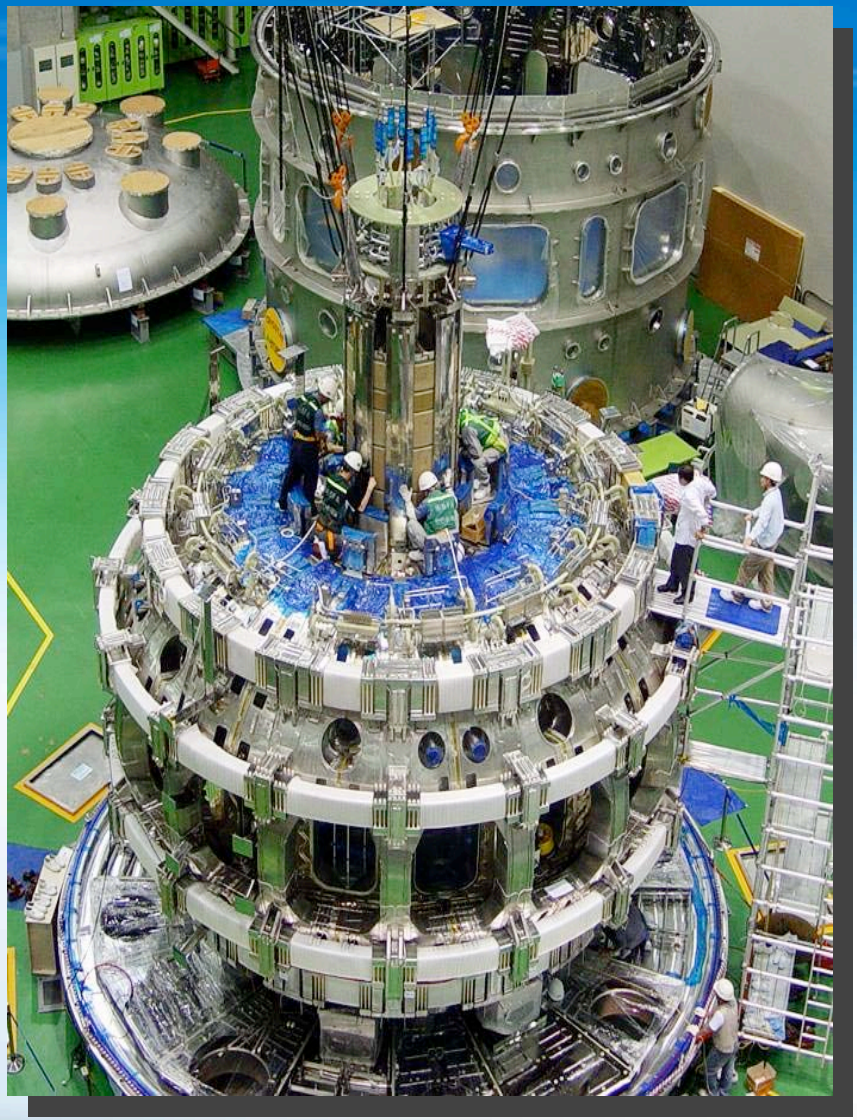
# Breakthrough in the superconducting magnet technology which is essential for fusion reactor



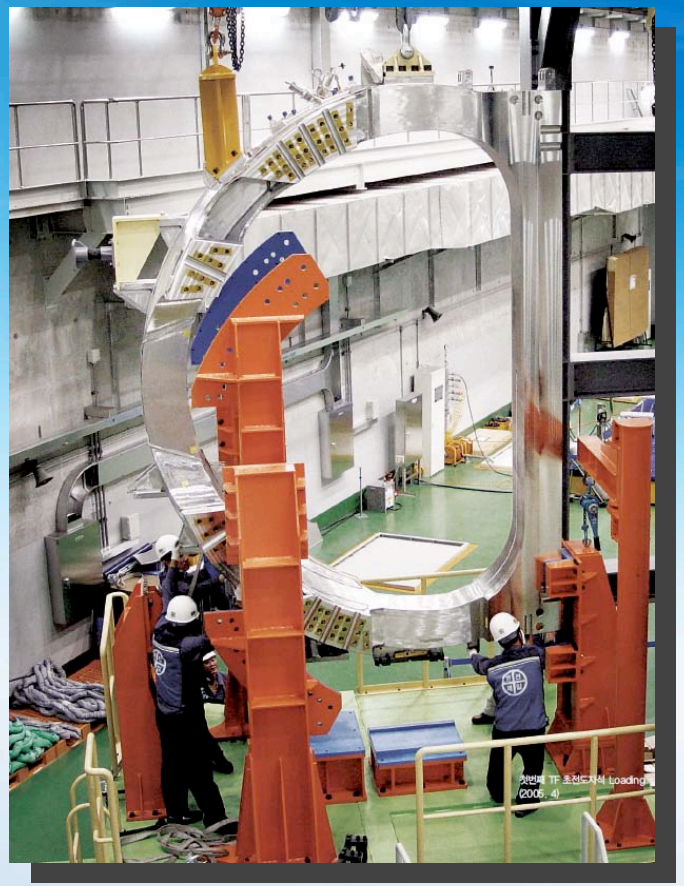


- KSTAR is unique device using fully superconducting magnets with same superconductor as ITER ($Nb_3Sn$).
- Magnet manufacturing technology has been qualified including heat treatment process (660 degree C for 40 days).

# Challenge in Superconducting Magnet Technology
## *- Central Solenoid Assembly (Oct. 2006) -*

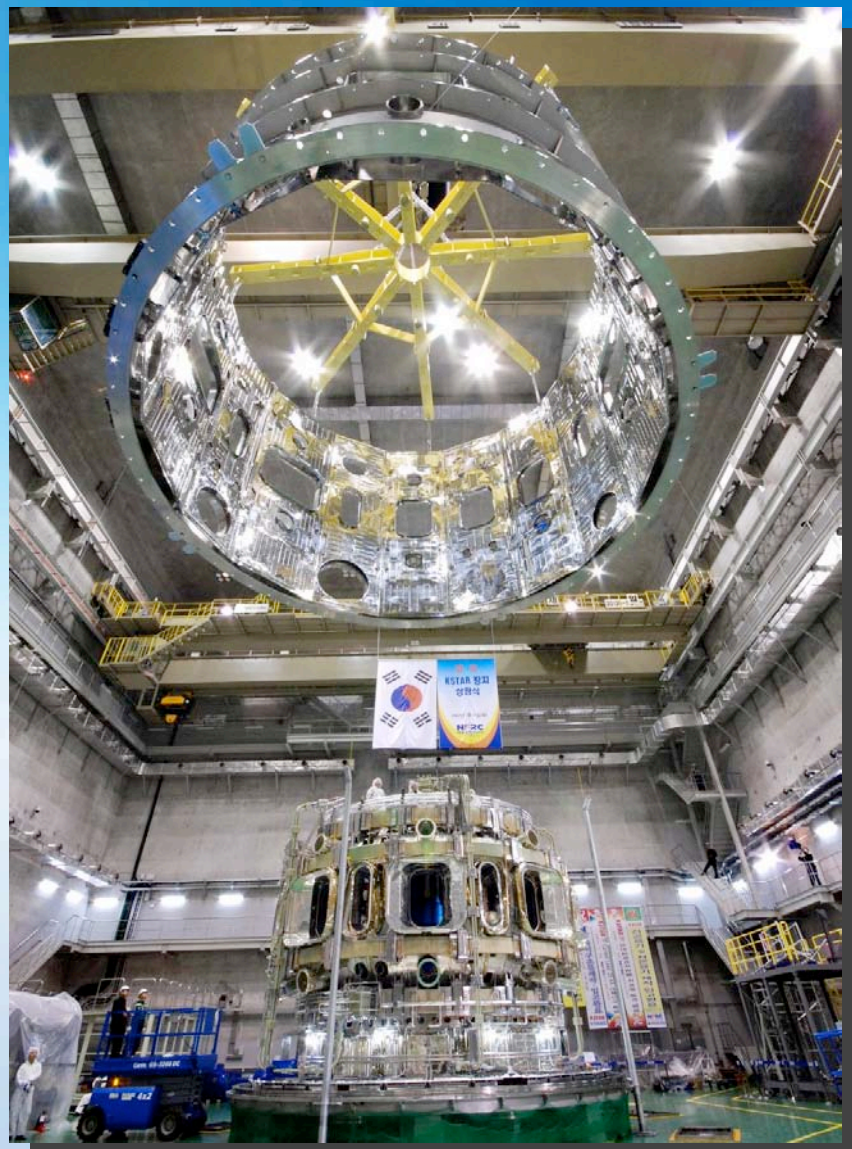


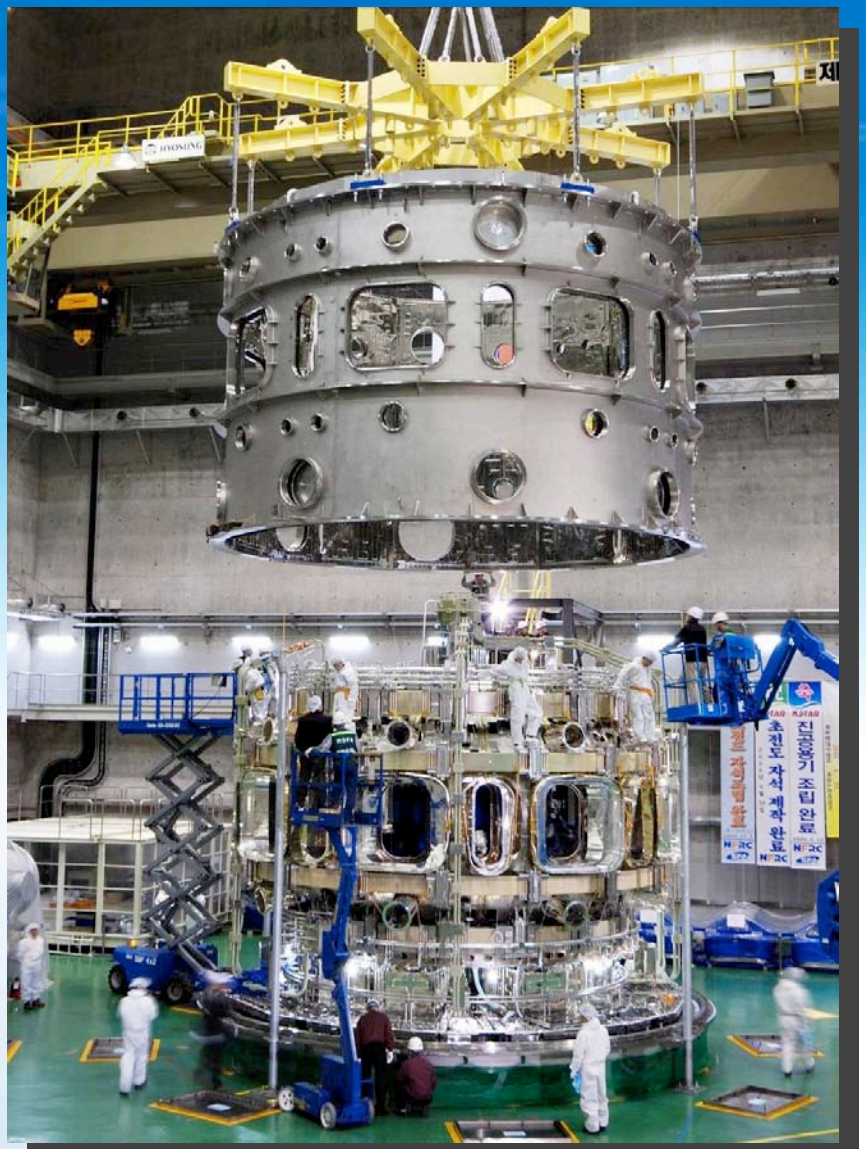
# New Approach of the Tokamak Assembly



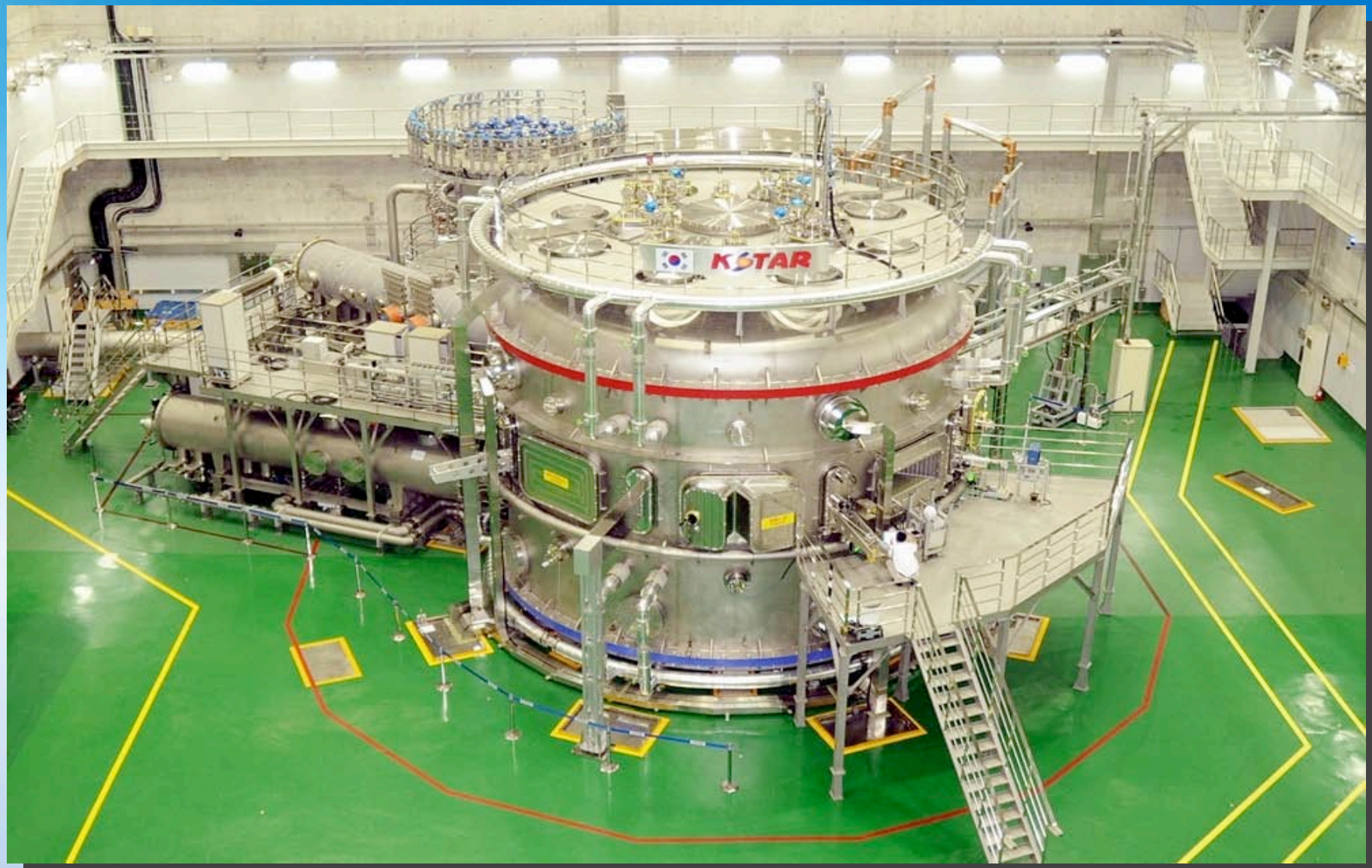

- New approach in magnet assembly by rotating each magnet along the vacuum vessel (assembling tolerance within 1 mm)

# Installation of Cryostat Cylinder (Jan. 2007)

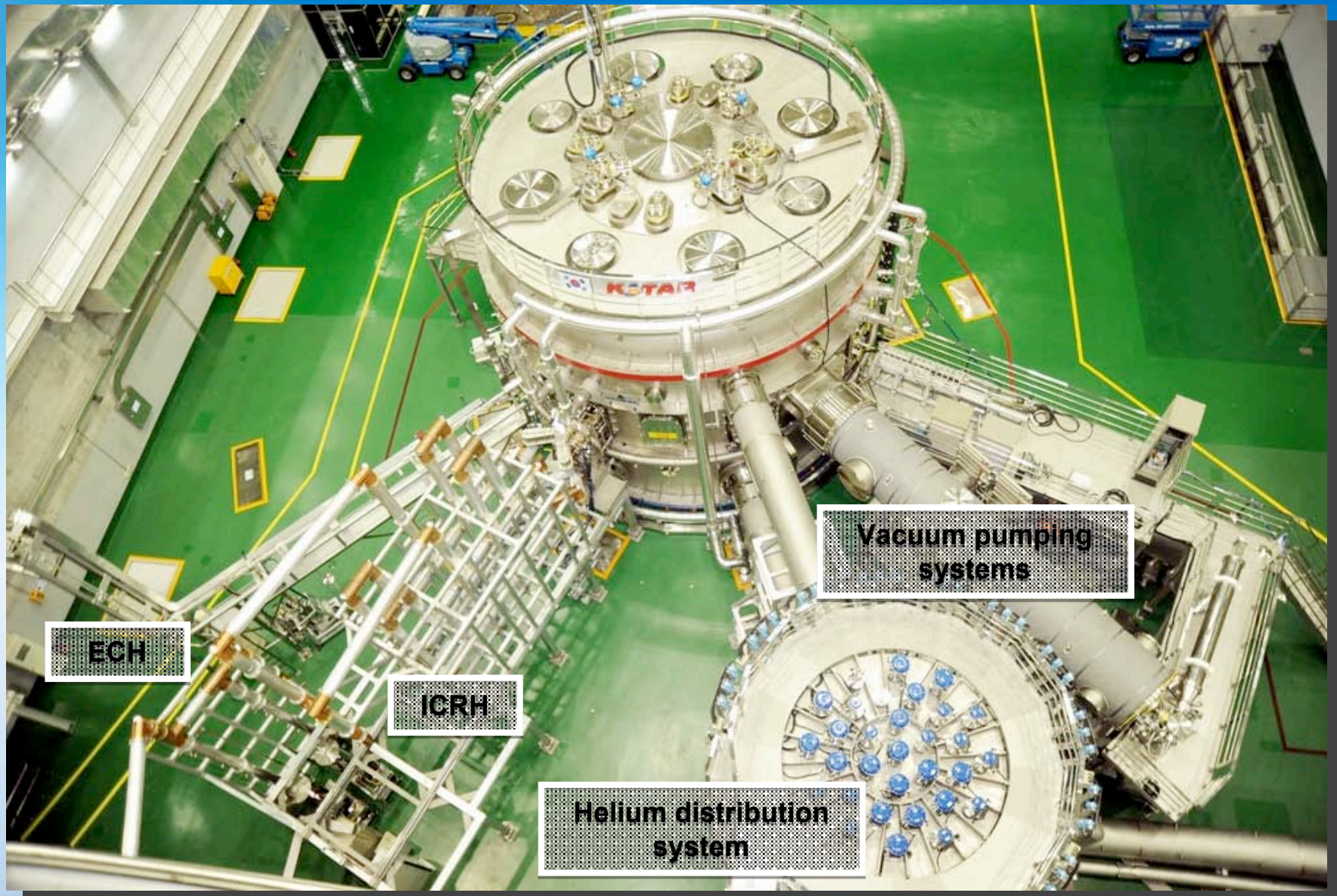




# Completion of the KSTAR Device (Aug. 2007)



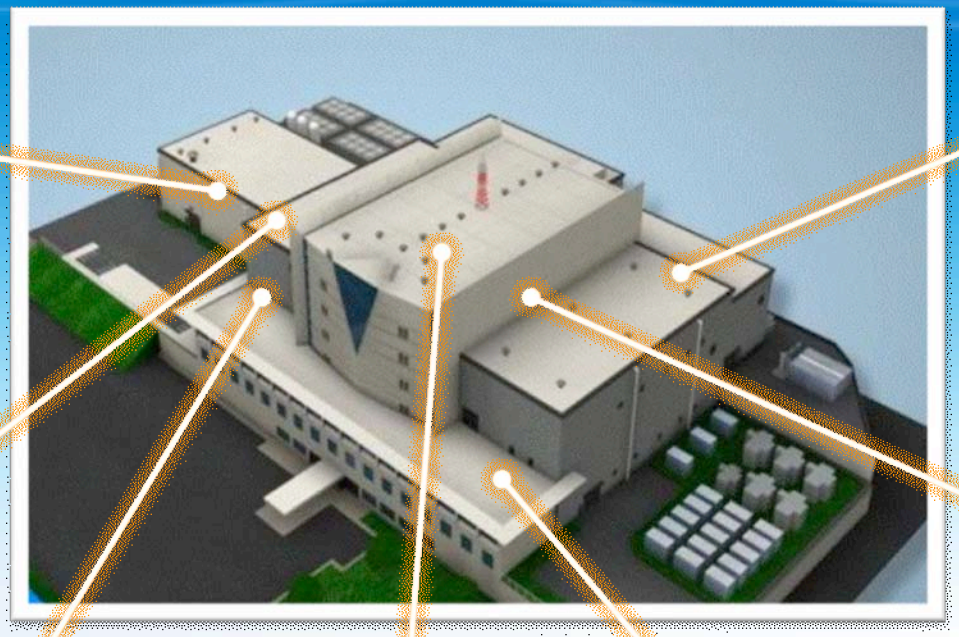
# Completion of the KSTAR Device (Aug. 2007)



# Qualified Industrial Participation on KSTAR Ancillary System Engineering

Cooling Water

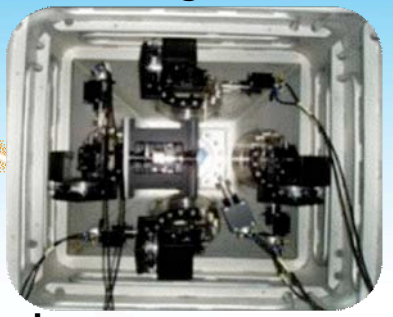
KSTAR Experimental Building



Heating

Cryo-facility

Diagnostics



Magnet Power Supply

KSTAR

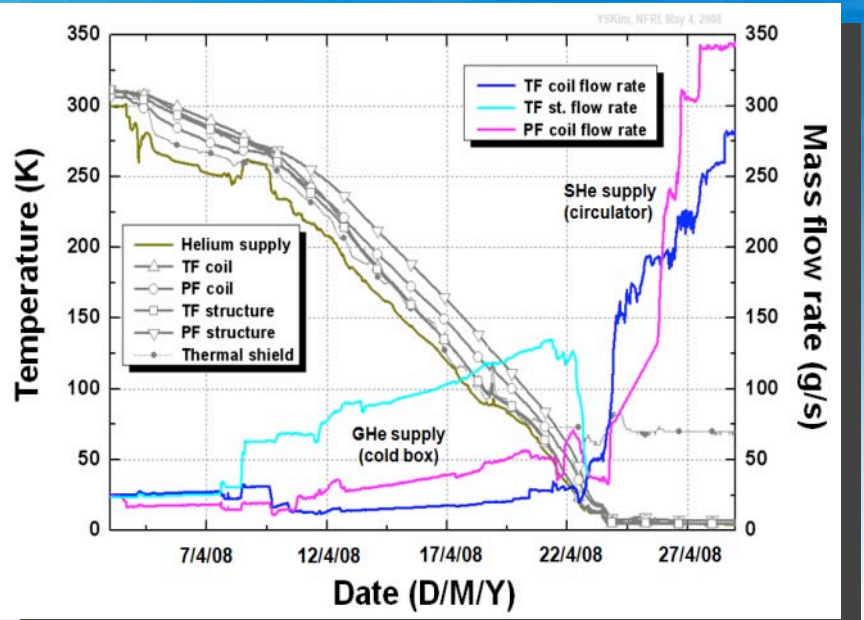
Central Control

# Dedication and Technological Advancements

## of Participating Industries : _69+


HYUNDAI HEAVY INDUSTRIES CO.,LTD.
DOOSAN 두산중공업
SAMSUNG 삼성전자
poscon
KISWIRE
SFA SFA ENGINEERING CORP.
KOPEC
대우건설
SONGWON EDWARDS LTD.
BOC EDWARDS
성원에드워드주식회사
(주)성도 이엔지
PHILOSOPHIA
4D Technology™ for Systems Engineering
하늘엔지니어링
주식회사 한라이비텍
Electron Beam Weld Engineering Laboratory
SeAH SeAH Steel Corp.
GS 건설
HANYANG ENG
Wonshin
금강기전
SAMSUNG 삼성중공업
SAMSUNG 삼성SDS
COMTECS
SAM YOUNG
KoSPI
GENESIS Technologies Inc.
3RLab
SINCE 2000

# Engineering verification by the successful integrated commissioning at the first trial

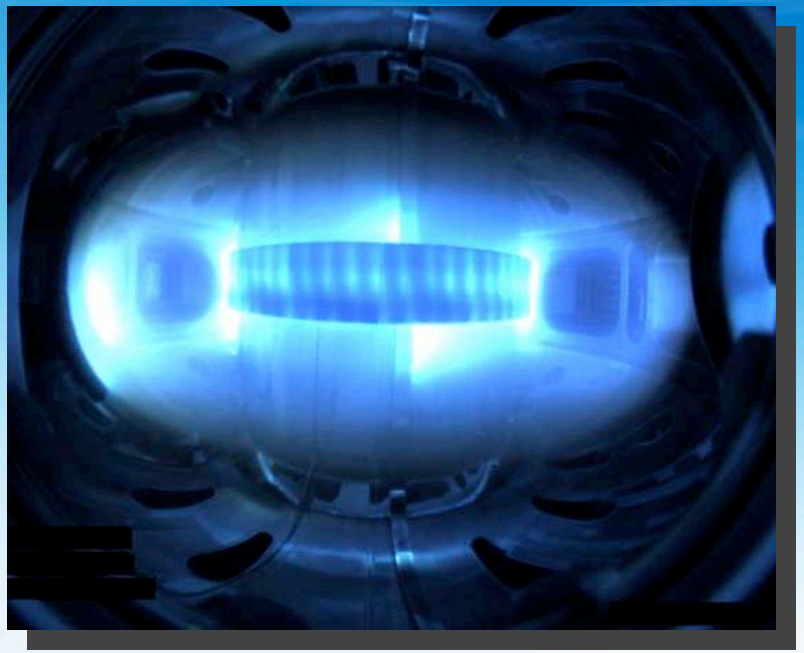



SC Magnet Cool-down

Control Room

- Whole magnet system was cooled down to 4.5 K without leak in th e cryostat.
- All superconducting magnets operated stable without any quench up to 35 kA.

# Successful first plasma is possible due to Quality Assurance based engineering

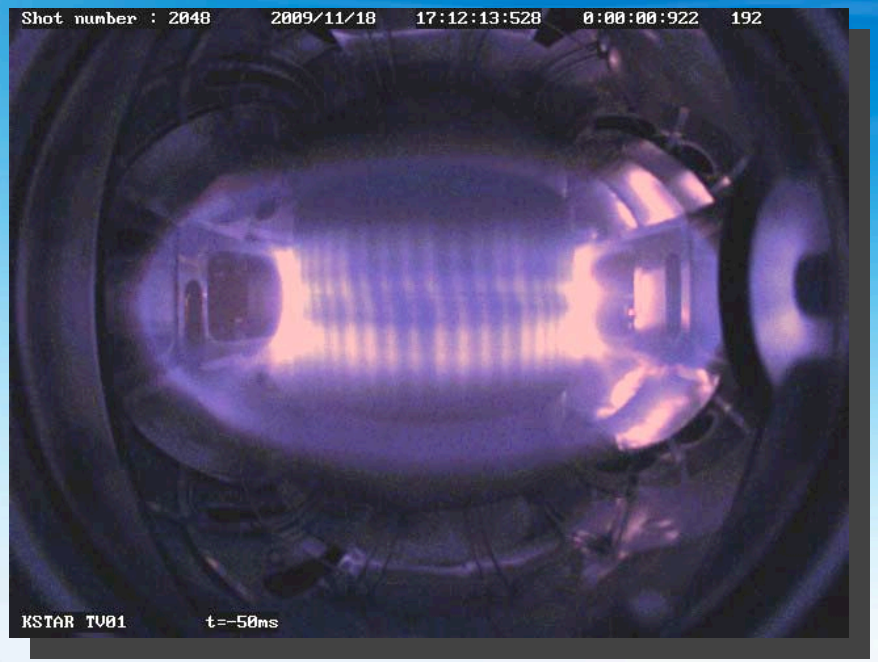


First plasma ($H_2$)

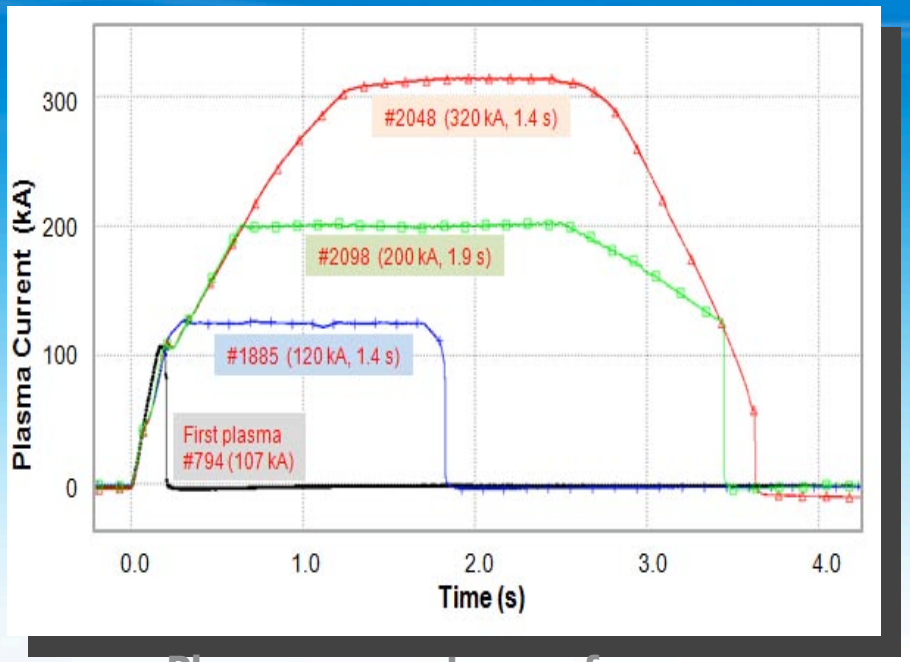

July 15, 2008: Celebration for KSTAR's achi evement on First Plasma Milestone

- Korea is one of the world's leaders in the construction of large-scale re search devices, capitalizing on cutting-edge technologies for extreme e nvironments including ultra high vacuum, ultra low temperature and su perconductor technologies.

# Start Joint Experiments from the KSTAR 2nd Campaign



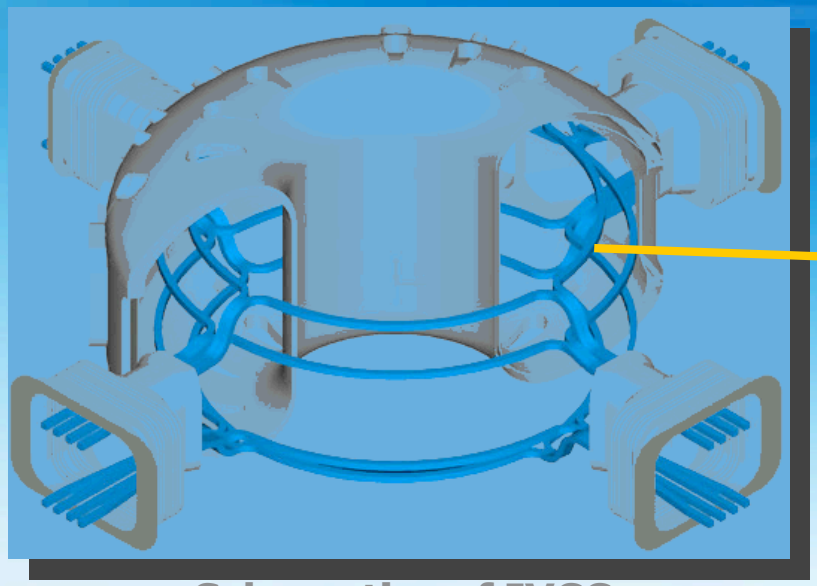

2nd Campaign plasma ($D_2$)



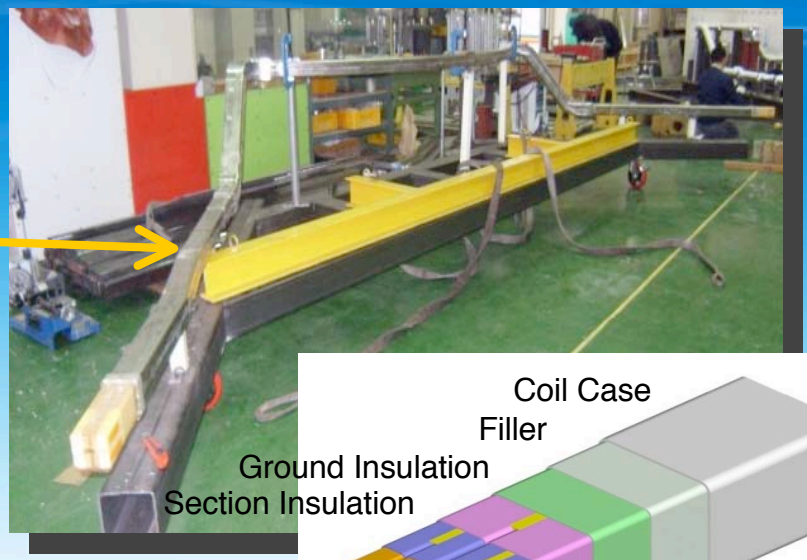

Plasma current waveforms
(320 kA, flat-top 1.4s, pulse 3.6s)

- As the closest realization of ITER, KSTAR will serve as a "pilot device" during the construction of ITER.

# Advanced plasma control research using in-vessel control coil system

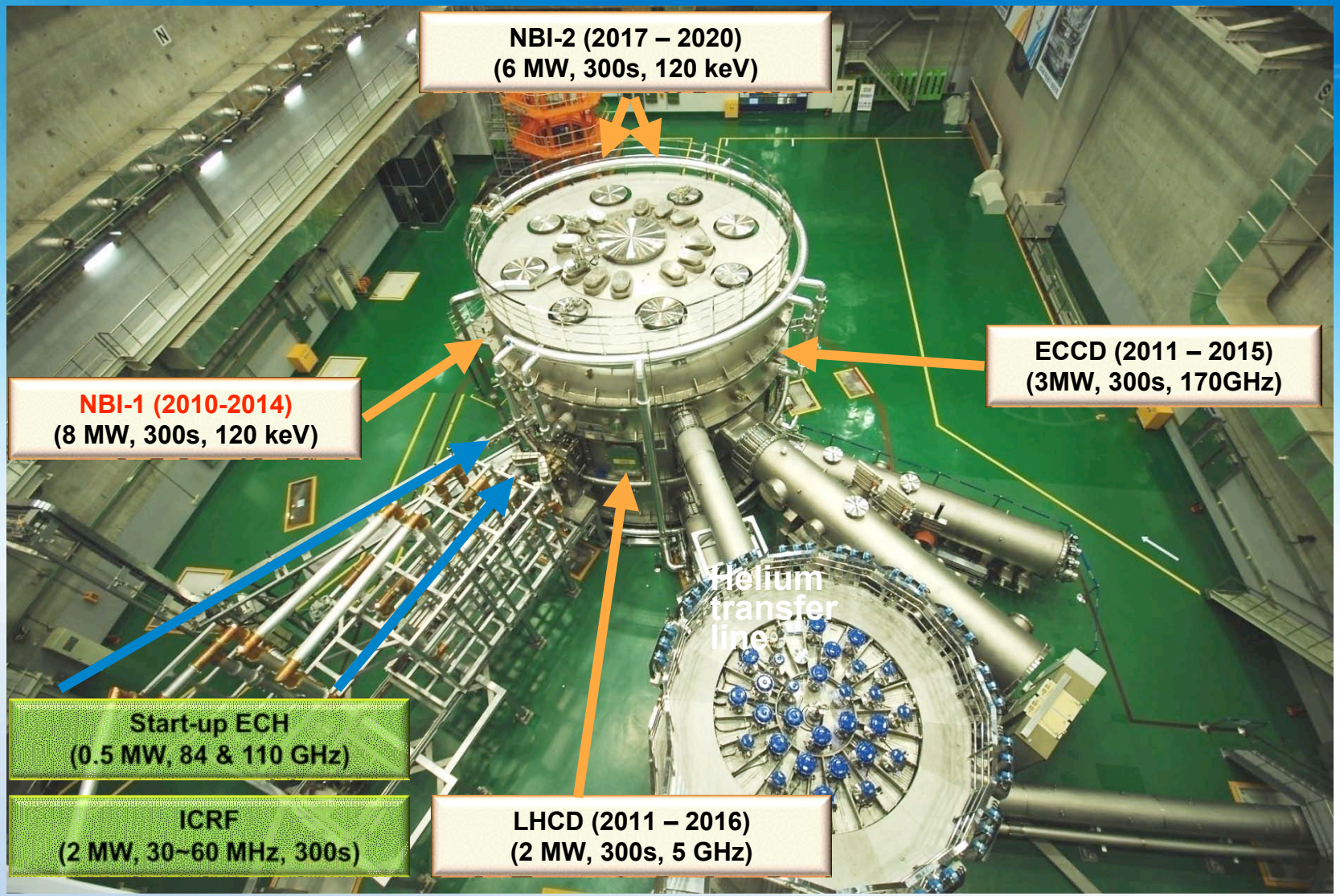


Schematics of IVCC




- **Multi-functional in-vessel coils for vertical and radial stabilizing, err or field correction, ELM control and fast RWM control**

# High temperature plasma research adopting long -pulse capable heating systems

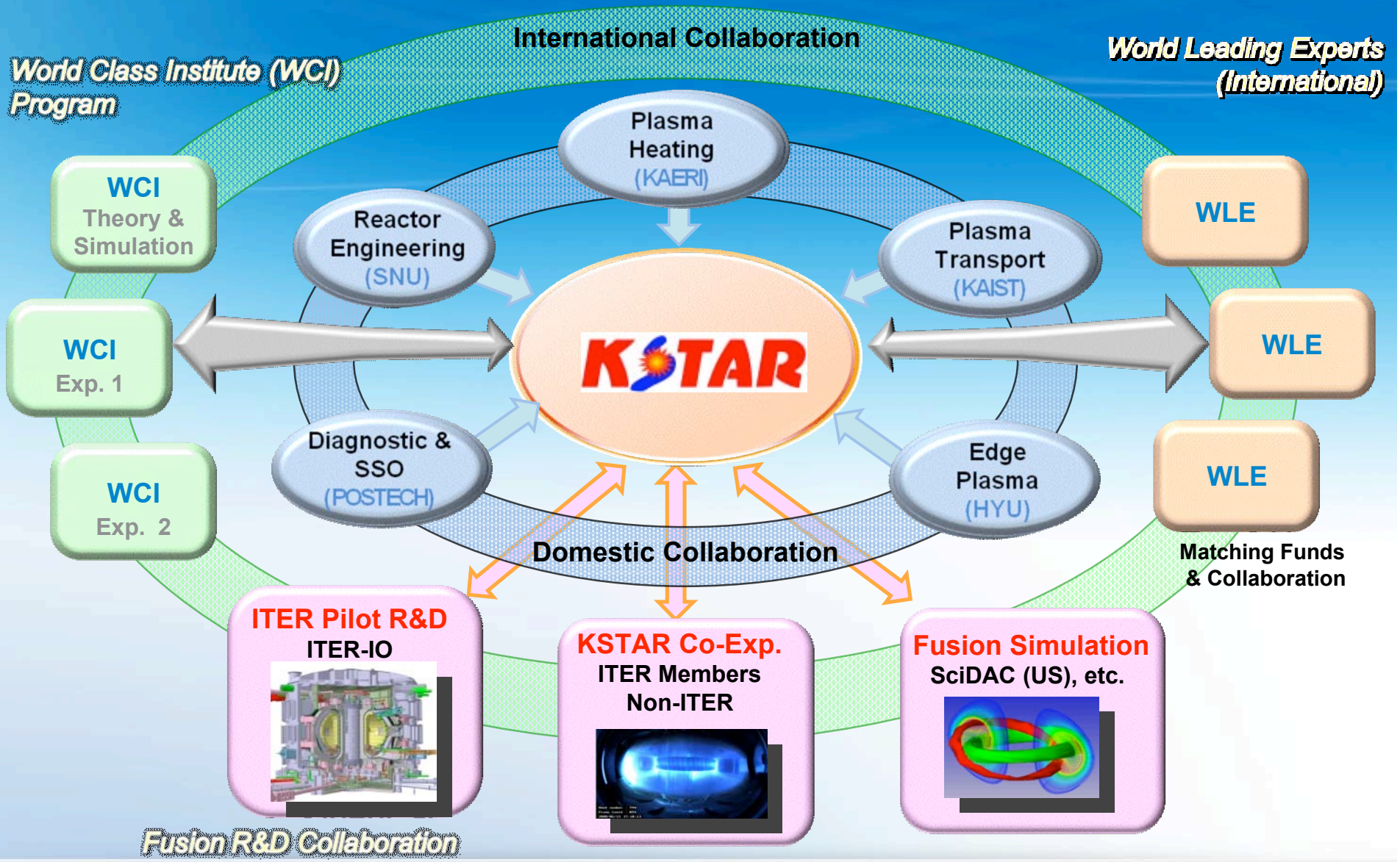


# KSTAR will be operated as an international collaboratory for fusion science & technology

| Operation Phase I<br>2008 ~ 2012 | Operation Phase II<br>2013 ~ 2017 | Operation Phase III<br>2018 ~ 2022 | Phase IV<br>2023 ~ |
|---|---|---|---|
| **SC Tokamak operation** | **Long-pulse operation** | **High performance operation** | **DEMO test bed** |
| • Superconducting tokamak operation<br>• First plasma & inductive current ramp (2 MA)<br>• Plasma shaping & heating (DN & SN, H-mode) | • Steady-state operation & ITER pilot device roles (300 s+)<br>• Plasma heating & non-inductive current drive<br>• Instability control in H-mode and AT-mode | • Advanced scenario for DEMO beyond ITER<br>• High-beta and high bootstrap current scenario<br>• Extreme operation of the superconducting tokamak | • DEMO Engineering<br>• DEMO simulator<br>• Reactor material test |

- First Plasma (‘08)
- Current & Position control (‘09)
- Divertor plasma (‘10)
- H-mode operation (‘11)
- Fast stabilization (‘12)

# Collaboration Framework for KSTAR



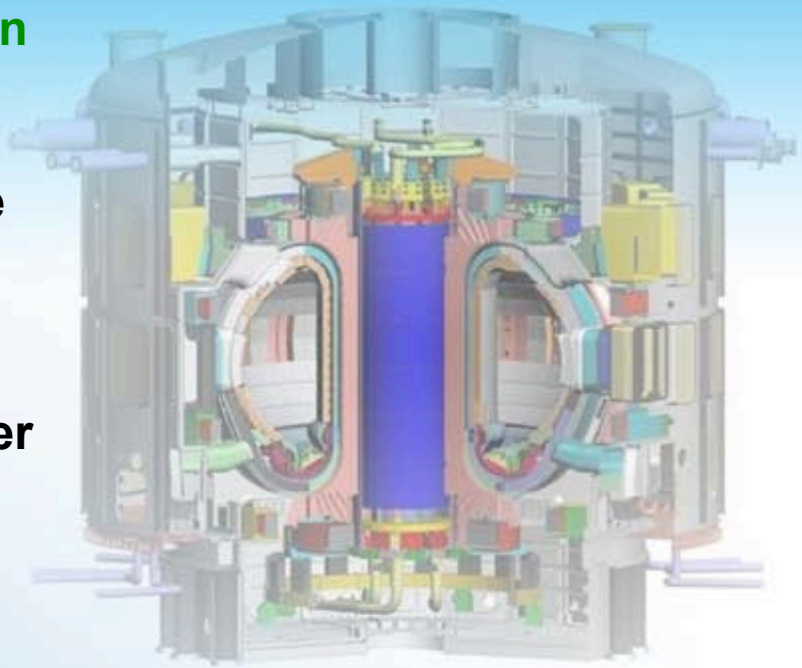

ITER
Program
in Korea

# ITER Project

## Purpose

To demonstrate *scientific and technological feasibility* of fusion energy for peaceful purposes, an essential feature of which be achieving sustained fusion power generation (JIA Article 2).

- Designed to produce 500 MW of fusion power for an extended period of time.
- Q ~ 10: fusion power is 10 times more than needed to run it.
- Demonstrate or develop all the new technologies required for fusion power plants, except materials endurance.



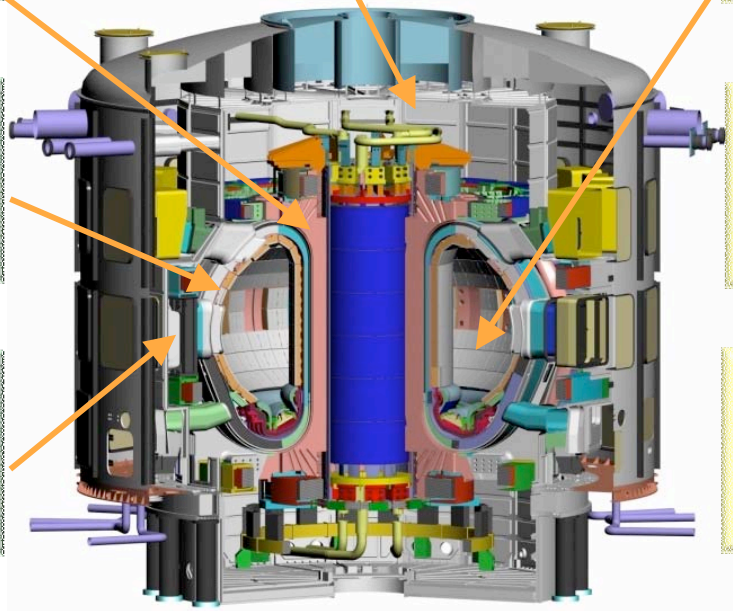
# In-kind Contribution of Korea

**1. TF Conductor**
Total Value (kIUA) : 215.0
KO Allocation : 21.18%
KO Contribution (kIUA) : 43.39

**2. Vacuum Vessel Main Body**
Total Value (kIUA) : 124.2
KO Allocation : 21.1%
KO Contribution (kIUA) : 26.2

**3. Vacuum Vessel Port**
Total Value (kIUA) : 78.5
KO Allocation : 73.5%
KO Contribution (kIUA) : 57.7

**7. Thermal Shield**
Total Value (kIUA) : 28.8
KO Allocation : 100%
KO Contribution (kIUA) : 28.8



**4. Blanket First Wall**
Total Value (kIUA) : 87.0
KO Allocation : 10.48%
KO Contribution (kIUA) : 9.12

**5. Blanket Shield Block**
Total Value (kIUA) : 58.0
KO Allocation : 10.48%
KO Contribution (kIUA) : 6.08

**6. Assembly Tools**
Total Value (kIUA) : 22.0
KO Allocation : 100%
KO Contribution (kIUA) : 22.0

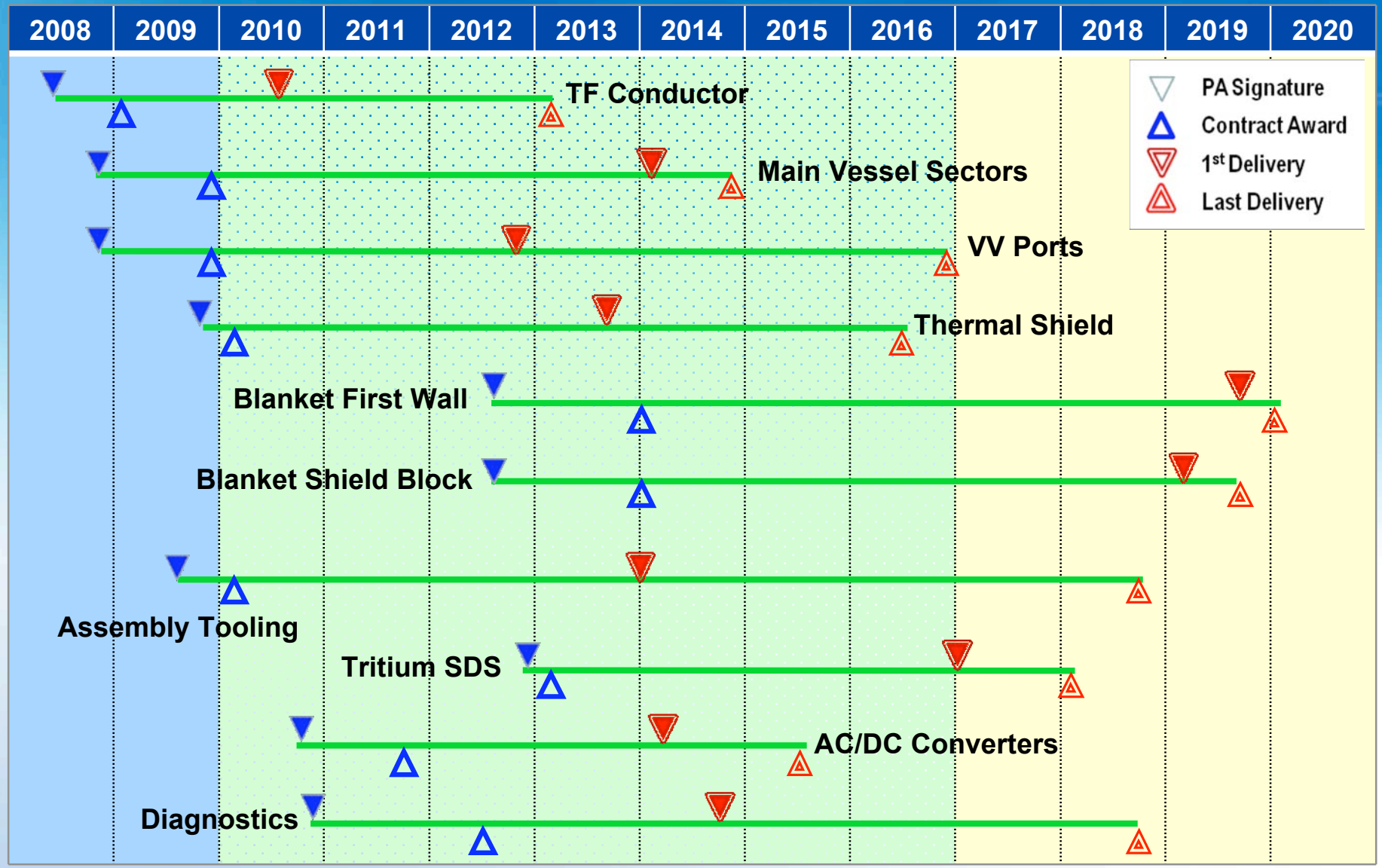
**8. Tritium SDS**
Total Value (kIUA) : 14.5
KO Allocation : 88%
KO Contribution (kIUA) : 12.76

**9. AC/DC Converters**
Total Value (kIUA) : 82.2
KO Allocation : 38%
KO Contribution (kIUA) : 31.24

**10. Diagnostics**
Total Value (kIUA) : 137.5
KO Allocation : 3.54%
KO Contribution (kIUA) : 4.88

Leading Items | Tokamak Main | Ancillary

# Procurement Schedule of Korea



# First Signing PA for TF Conductor (May 2008)

15.5. Annex C shall contain the credit request form.

**Article 16. Precedence**

In case of conflict, the provisions of the ITER Agreement, other documents referred to in the preamble and Council decisions shall have precedence over this PA. Council changes occurring after agreement of this PA that effect the performance of this PA herein shall be incorporated in accordance with Article 10.

**SIGNATURES**

| For the DA, | For the IO, |
|---|---|
| Gyung-Su Lee, Director General | Kaname Ikeda, Director General |
| Signature: 이경수 GSLee | Signature: 池田要 |
| Done at Seoul, 7 May 2008 | Done at Seoul, 7 May 2008 |


**First signing for KO procurement package (3rd after JA and EU)**
**- TF conductor 20.18%, 19 km (760m: 10 EA, 415m: 9 EA)**

# Signing PAs for VV & Ports and Assembly Tooling

(19 Nov 2008)

Article 16 Precedence

In case of conflict, the provisions of the ITER Agreement, decisions of the ITER Council and other documents referred to in the preamble of this PA shall have precedence over this PA. Any decisions adopted by the ITER Council after the entry into force of this PA that effect the performance of this PA shall be incorporated in accordance with Article 13 herein.

SIGNATURES

For the DA,
Kijung Jung, Director General ITER Korea

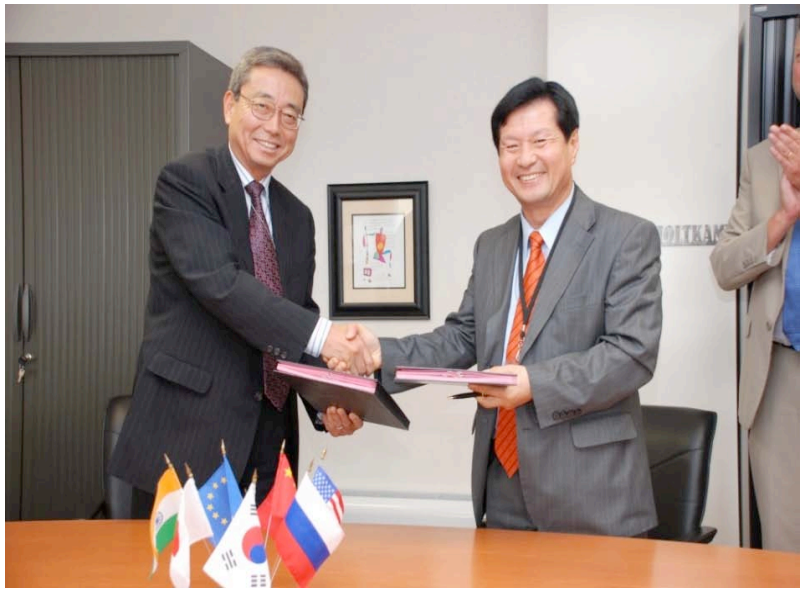
signature:

Done at Cadarache, 19th November 2008

For the IO,
Kaname Ikeda, Director General

signature:

Done at Cadarache, 19th November 2008



(3 Aug 2009)

In case of conflict, the provisions of the ITER Agreement, decisions of the ITER Council and other documents referred to in the preamble of the PA shall have precedence over the PA. Any decisions adopted by the ITER Council after the entry into force of the PA that effect the performance of the PA shall be incorporated in accordance with Article II.5 herein.

SIGNATURES

For the DA,
Kijung Jung, Director General

signature:

For the IO,
Kaname Ikeda, Director General

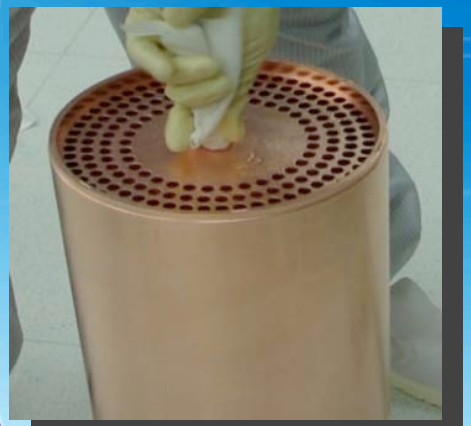
signature:

· Vacuum Vessel 20% : 2 Sectors
· VV Ports 73.5% : 17 Eq. & 9 Lower

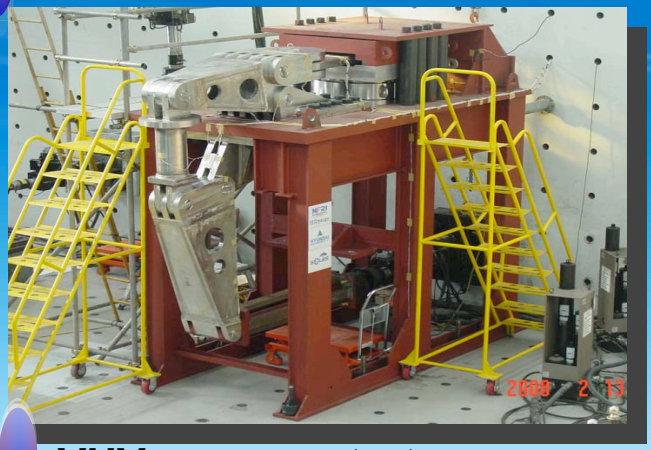
· Assembly Tooling 3-11: 100%

# ITER Procurement Activities of Korea

TF conductor and cable fabrication

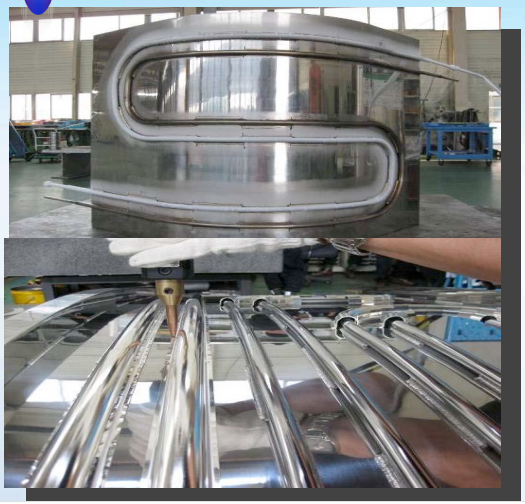


VV support mock-up

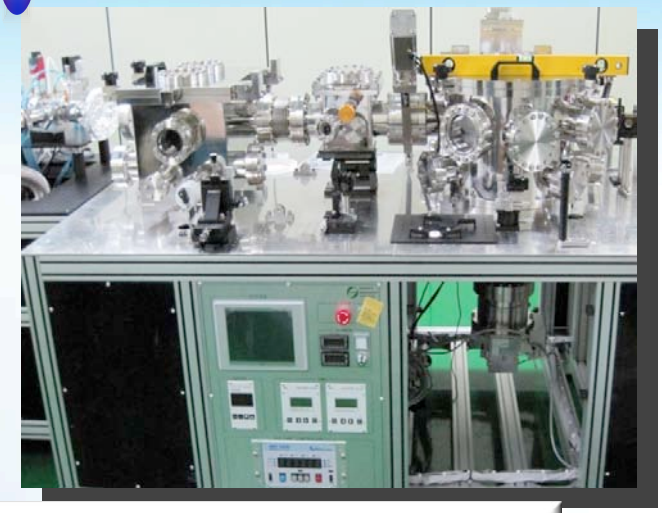


Blanket e-beam welding

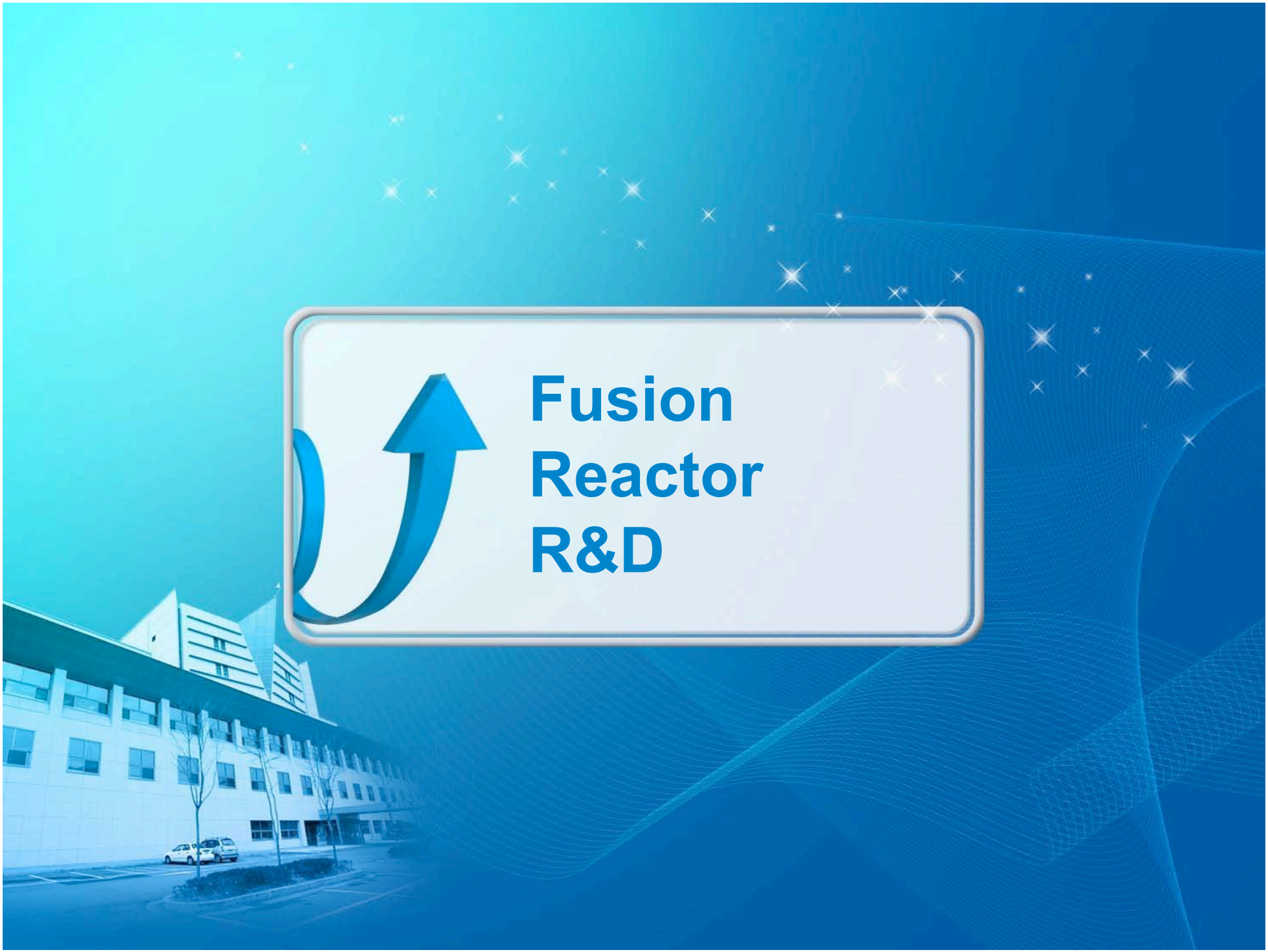
TS mock-up



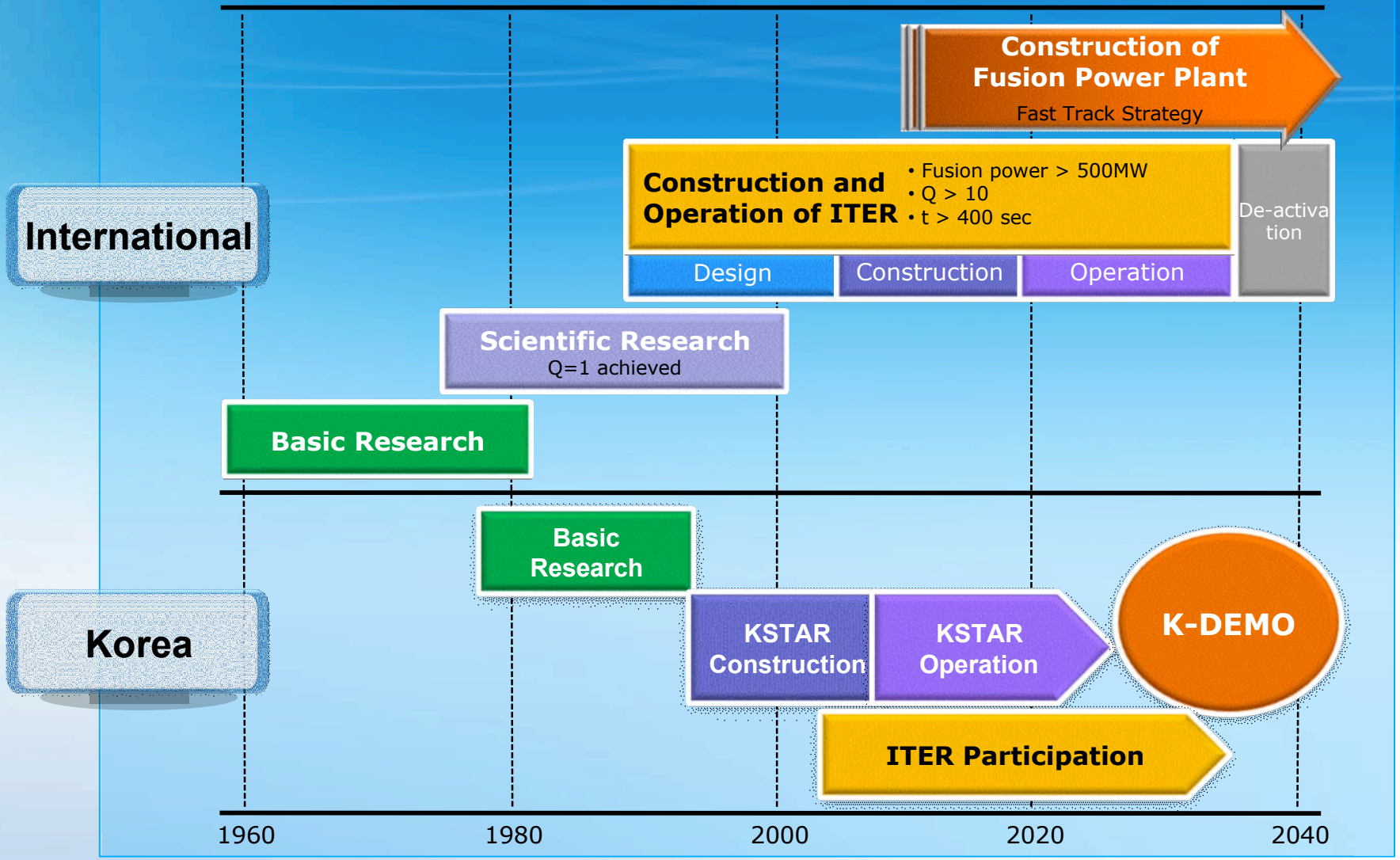
VUV spec. proto-type



**Korea is contributing to ITER design and R&D through Task Agreements between IO and KO-DA (23 topics by 2009)**


Fusion
Reactor
R&D

# Global Leader in Fusion Reactor Development



# Korean Demonstration Fusion Rector (K-DEMO)

## Site Options for K-DEMO

- Tritium supply from heavy water reactor
- Low-and intermediate-level radioactive waste repository
- Large-capacity power transmission facilities


Policy
Decision
and
Implementation

# Fusion Energy Development Promotion Law (FEDPL)

## Purpose of the FEDPL

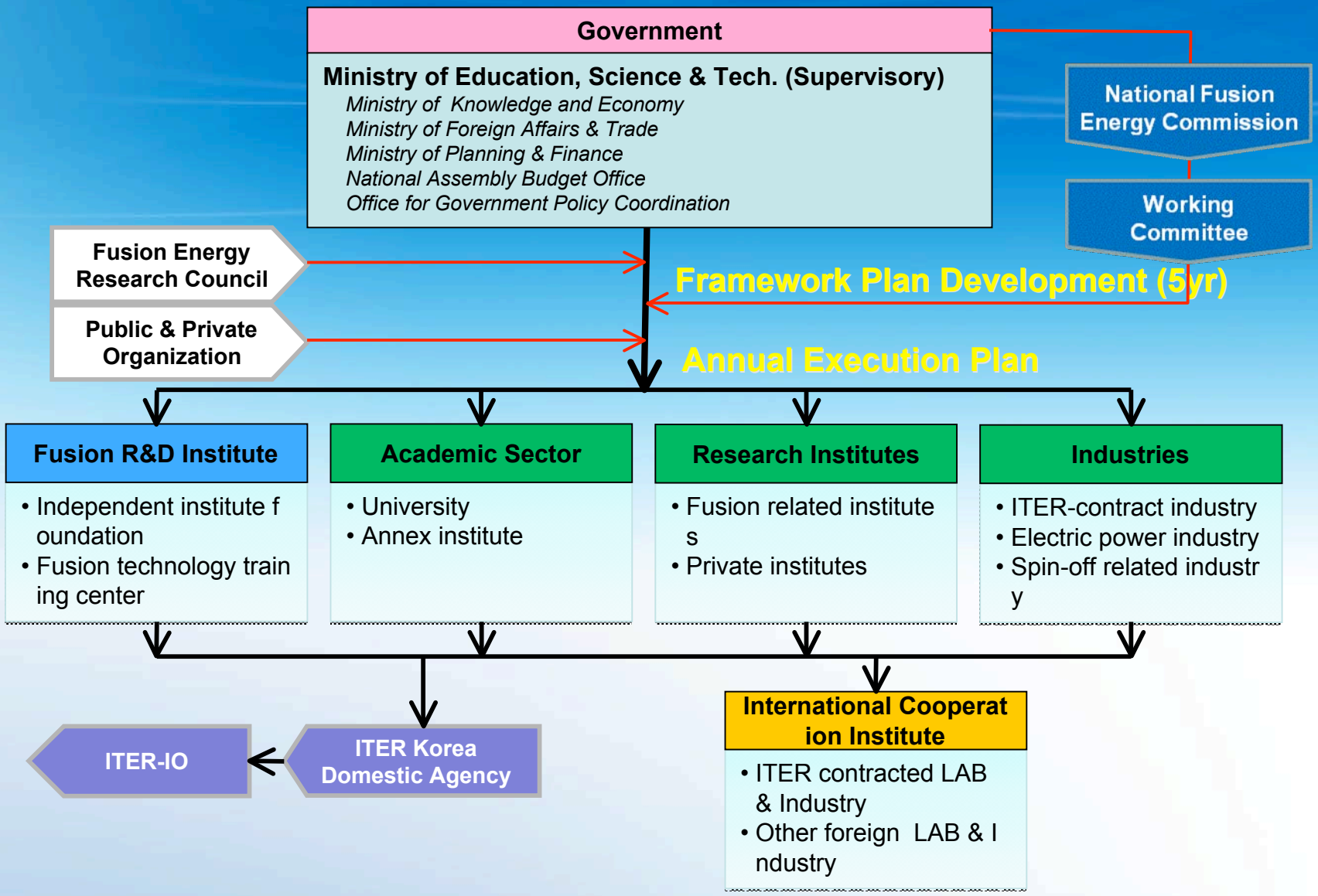
- To establish **a long-term and sustainable legal framework** for fusion energy development phases
- To **promote industries and institutes** which participating the fusion energy development by supports and benefit
- The **first country in the world** prepared a legal foundation in fusion energy development

## History of the FEDPL

- 1995. 12 : National Fusion R&D Master Plan
- 2005. 12 : National Fusion Energy Develop. Master Plan

- 2007. 3 : Fusion Energy Development Promotion Law
- 2007. 4 : Ratification of ITER Implementation Agreement and entrusted to IAEA
- 2007. 8 : Framework Plan of Fusion Energy Development

# Policy and Decision Making System



# Vision, Phased Goals & Strategy in FEDPL

**Securing sustainable New Energy through the Fusion Energy Technology**

| | 1st Phase (2007~2011) | 2nd Phase (2012~2021) | 3rd Phase (2022~2036) |
|---|---|---|---|
| **Strategic Goals** | Establishing the base of developing fusion energy | Becoming one of the leading countries in fusion energy research | Obtaining the ability for fusion power plant construction |
| **Detailed Strategic Goals** | Obtaining the operation technologies for KSTAR | Advancing the KSTAR & Implement a role of worldwide fusion research machine | Obtaining key technologies and performing the key Role of ITER operation |
| | Participation in the Construction of ITER | Contributing to ITER Construction and securing Key technologies | Leading the DEMO construction and demonstrate the fusion power generation |
| | Development of the engineering system for fusion power plant | Securing engineering Design & key technologies for DEMO | Completing the engineering design for Korean fusion Power plant |
| | Establishment and expansion Of the base of R&D and Application Technology | Expansion of industrialization in fusion related technologies | Creating the growth engine by Fusion related technologies |

**Long Term Goals**

- KSTAR operation as a world leading fusion device
- Leading role in the ITER construction and operation
- DEMO development participation and build up knowledge for fusion power plants
- Creating industries using fusion related technologies


• Date : October 10 ~ 16, 2010
• Place : Daejeon Convention Center
Daejeon City, Republic of Korea
• Organized by IAEA and
Hosted by Ministry of Education, Scie
nce & Technology through National F
usion Research Institute
• Pre-conference (Oct. 7~9, 2010)
International Green Forum,
International Youth Conference,
Green Festival, and
Cultural Experience
You can meet the cutting edge of Fusion Technology


Thank you for your Attention !