

# ***R&D of 22.9kV/50MVA HTS Transmission Power Cable in Korea***

*Jeonwook Cho*

*Korea Electrotechnology Research Institute*

*jwcho@keri.re.kr*

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- Introduce the DAPAS Program
- Research Activity
- Conclusion

DAPAS

# 21<sup>st</sup> Century Frontier R&D National Project



MOST established 21 frontier R&D Projects.

## The 21<sup>st</sup> Century Frontier R&D Project by MOST

- : started from 1999
- : to realize advanced economy and to level up the quality of people's life by improving significantly the Nation's competitive edge.

Now, the 21st century emphasizes more heavily on emerging technologies.

- IT, BT, NT, ET, ST

## MOST

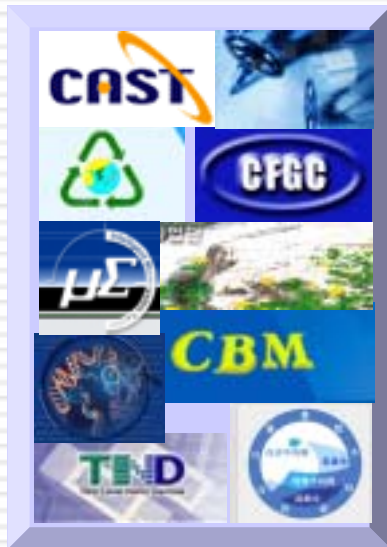
: selected 23 technologies (superconductivity technology is one of them)

- Superconductivity technologies, Biotechnology
- Information technology, Nano-technology
- Conventional industrial technologies.



# Total 23 Projects

DAPAS is one of them.



- Industrial Waste Recycling R&D Center
- Intelligent Microsystem Center
- The Center for Functional Analysis of Human Genome
- Tera-level Nanodevices
- Plant Diversity Research Center
- Crop Functional Genomics Center
- Center for Advanced Materials Processing
- Sustainable Water Resources Research Center
- Center for Biological Modulators
- **Center for Applied Superconductivity Technology**
- ...
- ...

- Each project is supposed to be funded about 100 million US dollars for ten years from government.
- So far it works as government promised.

# DAPAS program

Korean National Program for Super...

## DAPAS program

- **D**ream of **A**dvanced **P**ower system by **A**ppplied **S**uperconductivity tech.
- **name** of the “superconductivity frontier program in Korea”
- selected on May. 2001 by MOST

The primary target

→ R & D and **commercialization** of the developed HTS products

Budget

**10 years 146 million \$**

**Gov. : 100 & Indu. : 46**

**2003.08-2004.06**

**14 million \$ Gov. : 10 & Indu. : 4**

IT

Energy

Environment

## Independent Organization

### Center for Applied Superconductivity Technology

- Independent organization to manage and supervise DAPAS ; establishes R&D goal and plan, select and evaluate each projects



# Development targets for each phase

10 year program

Phase	1 <sup>st</sup> Phase			2 <sup>nd</sup> Phase			3 <sup>rd</sup> Phase			
	FY	FY	FY	FY	FY	FY	FY	FY	FY	FY
FY	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Target	Core technology (to develop the HTS wire and system technology)			Pre-commercial pilot (to improve the 1 <sup>st</sup> phase technology and develop the prototype devices)			Commercialization (Field test and development of the industrial technology for commercialization)			
Underground cables	50MVA, 22.9kV cable			500MVA, 154kV cable			1GVA, 154kV cable			
Transformers	1MVA, 22.9kV Single phase			5MVA, 154kV Single phase			100MVA, 154kV Tree phase			
Fault-current limiters	6.6kV, 200Arms SFCL			22.9kV, 620Arms SFCL			154kV, 2kArms SFCL			
Motors	100~ hp motor			1MVA~ motor			3~5MVA motor			

# Status of Korea Power System

## ✓ Voltage Level in Korea

**Transmission level : 765kV (Overhead Only)**

**345kV (Overhead + Underground)**

**154kV (Underground in Urban Area)**

**Distribution level : 22.9kV**

**There is no between 154kV and 22.9kV**

## ✓ Electrical demand keep growing constantly

**44 GW(2002) → 62GW (2010)**

## ✓ Increase Underground Transmission Line

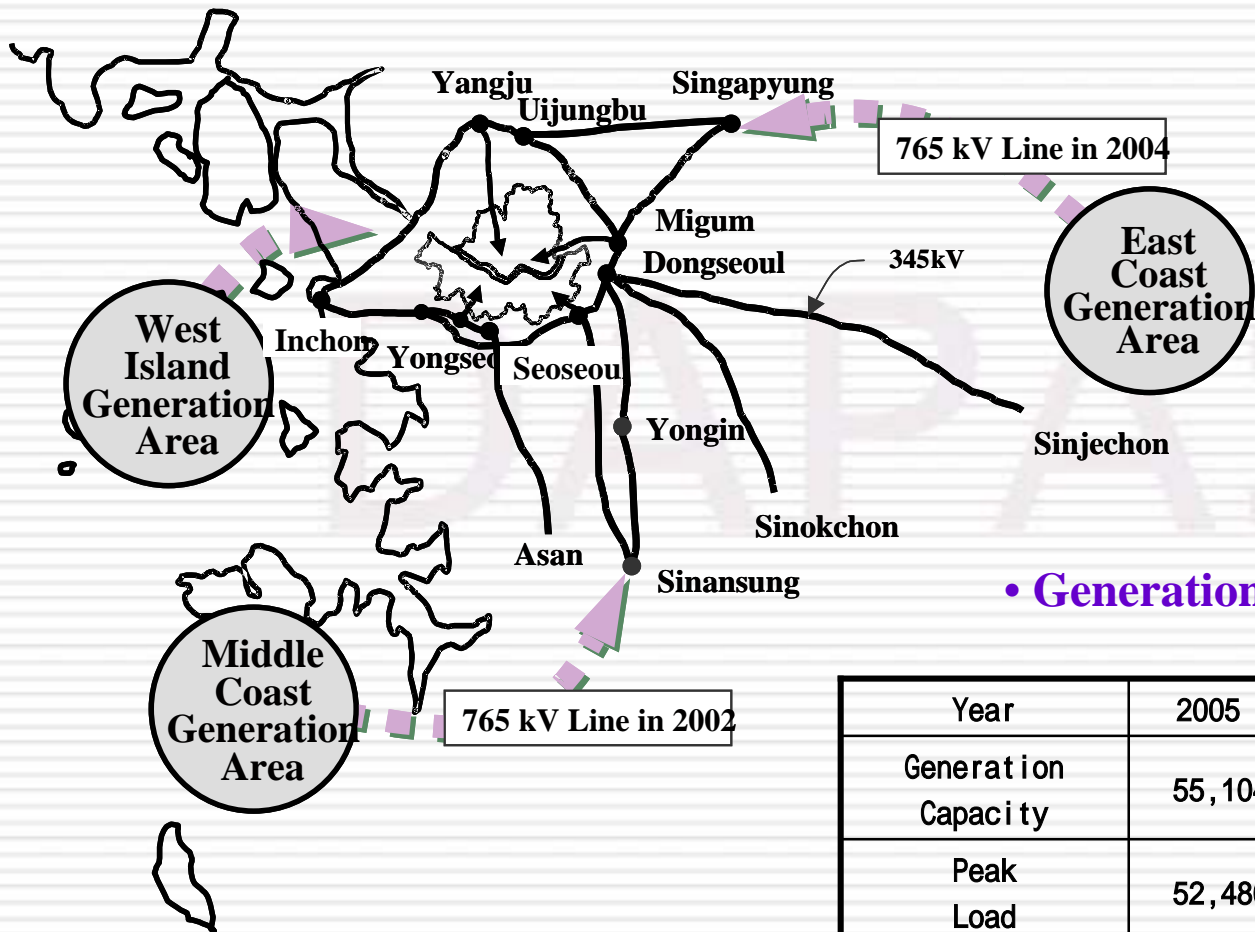
**154kV : 7% (now) → 12% (2010)**

**22.9kV : 8.7%(17,231 C-km) → 10.9%(24,540 C-km, 2010)**



# Power System Planning

## • Long term Power system planning of and its environs



## • Generation and load forecast

Unit : [MW]

Year	2005	2015	2025	2035
Generation Capacity	55,104	73,048	88,610	107,487
Peak Load	52,480	69,570	84,391	102,369
Seoul Load	8,581	12,592	18,460	27,064



## 全国电力供需紧张形势加剧

### China strives to ease power shortage in 2004

Electricity consumption has been growing by at least 15 percent on average for the past 17 months since June, 2002. Twenty - one provincial areas, or two thirds of China's total, had to limit the use of electricity due to power shortages

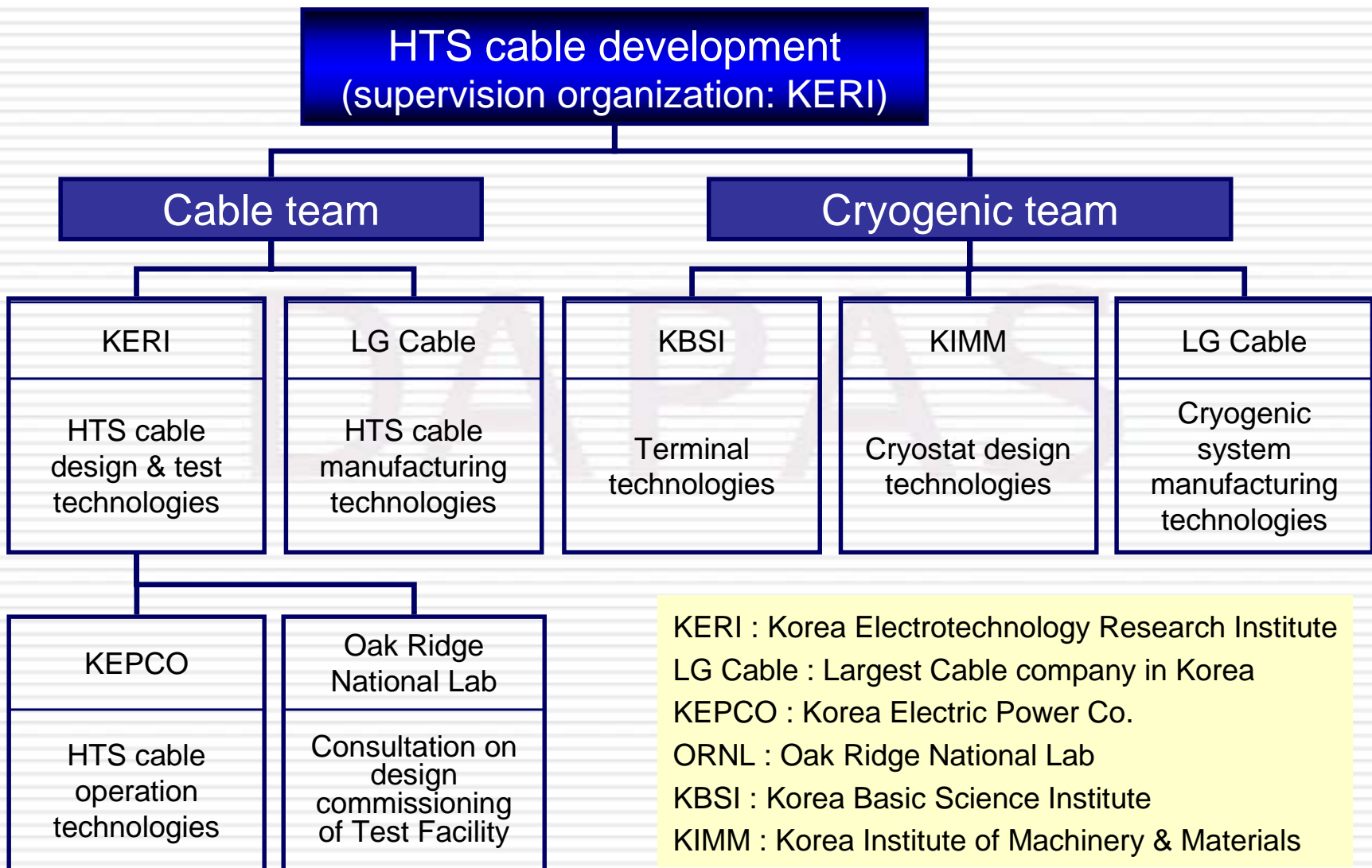
According to the State Grid Corporation, China's electricity consumption would grow to 2,091 billion kWh in 2004, up 207 billion kWh over 2003.

**Power shortage would worsen and more areas would encounter blackouts.**

# HTS Cable Specifications

- ✓ **Rated Voltage : 22.9kV**
- ✓ **Capacity : 50MVA**
- ✓ **Type of Cable : 3 Phase**
- ✓ **Cable Length : 30m**
- ✓ **Dielectric Type : Cold Dielectric**
- ✓ **Cryostat : 3 core / 1 Cryostat**
- ✓ **Cooling Cycle : LN<sub>2</sub> Cycling**
- ✓ **Operating Temperature : 70 ~ 80K**

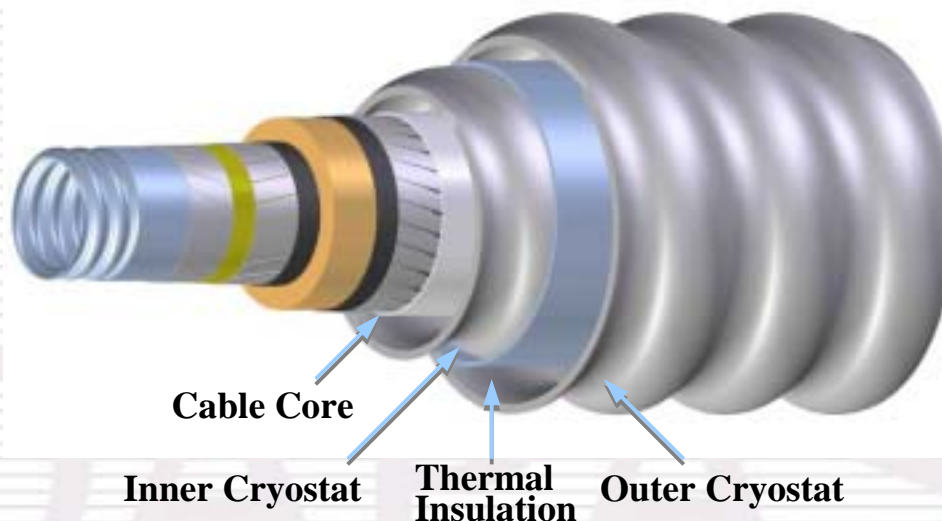
# Research Integration



KERI : Korea Electrotechnology Research Institute  
 LG Cable : Largest Cable company in Korea  
 KEPCO : Korea Electric Power Co.  
 ORNL : Oak Ridge National Lab  
 KBSI : Korea Basic Science Institute  
 KIMM : Korea Institute of Machinery & Materials

# HTS Cable Core design (1 phase)

## Description



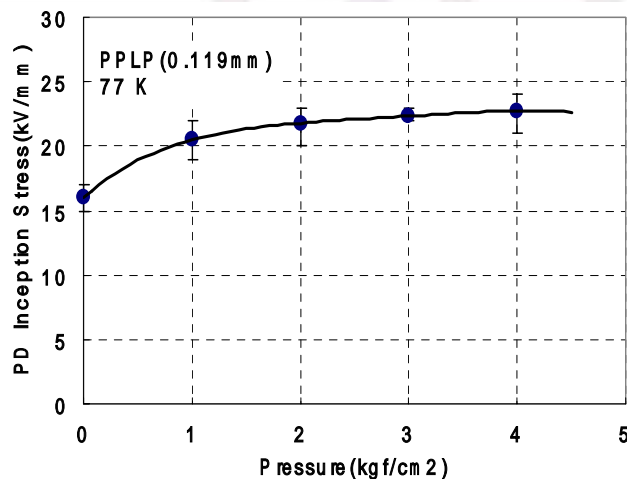
Structure		Material	Manufacturing Process
Core	Former	Stainless Steel 304	Taping / Drying / Stranding 3 Cores
	HTS Conductor	AMSC High Strengthen HTS tape	
	Electrical Insulation	Laminated PP Paper	
Cryostat	Inner Cryostat	Al	1 <sup>st</sup> Al Extruding, MLI and Spacer Taping 2 <sup>nd</sup> Al Extruding
	Thermal Insulation	Mylar tape, Polyester Mesh (MLI) Teflon (Spacer)	
	Outer Cryostat	Al	

# Cable Insulation Design

□ Base of KEPCO spec.(ICEA S- 61-402 Part 6)

Operation voltage(kV)	Impulse voltage(kV)		AC withstand voltage(kV)			DC withstand voltage(kV)
	Insulator	Shield	Long duration	Insulator	Shield	Insulator
25.8	150	40	80 (1 hour)	52 (10 min.)	4	100

□ Dielectric Design



$$E_{\max} = \frac{V}{r_1 \ln \frac{r_2}{r_1}}$$

Insulation thickness : 4.6 mm

(Partial discharge inception stress)

# Electric Insulation Test

## PD test



## AC test

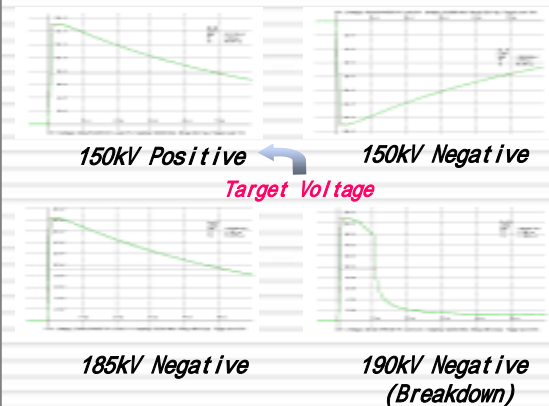
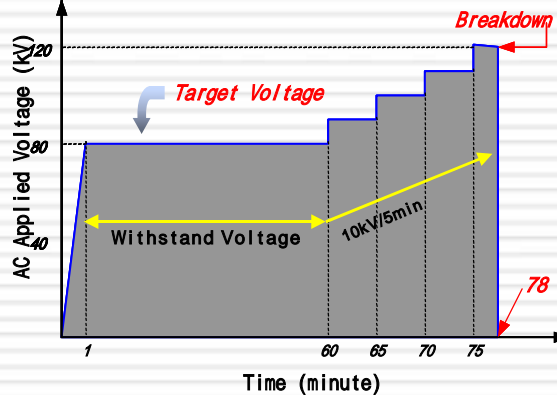


## Impulse test



Charge Voltage	Electric charge
< 28 kV	< 2 pC
28 – 30 kV	2 – 5 pC
> 30 kV	> 50 pC

\* Target : < 5 pC @ 23kV



# Machinery for HTS Cable



**For Cable Core**



**For 3 Core Combine**



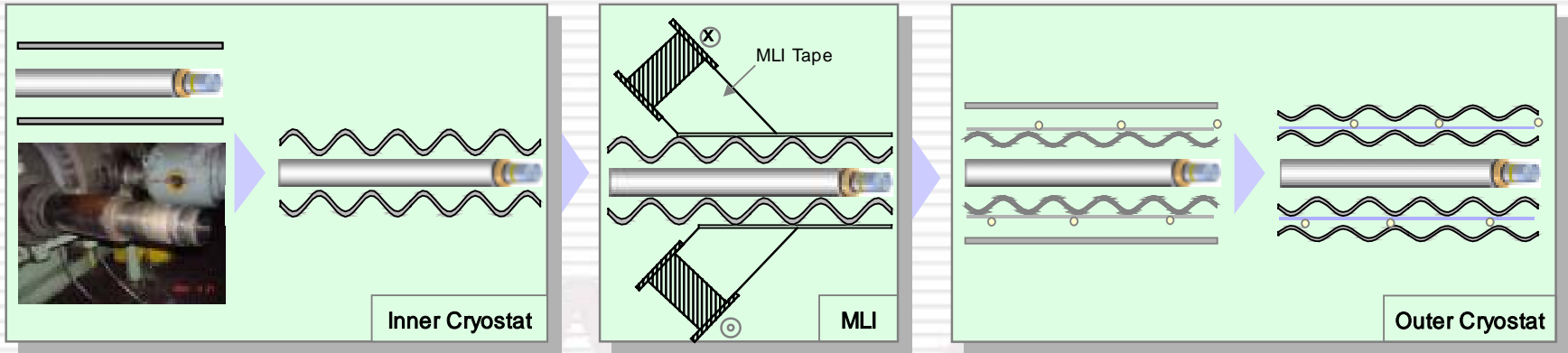
**Extruder for Cryostat**



**Extruder for Sheath**



# Cable Cryostat Manufacturing



Al Extrusion



MLI Taping



Outer Shape

# Manufacturing the HTS Cable & Cryostat



# 1 Phase Cable



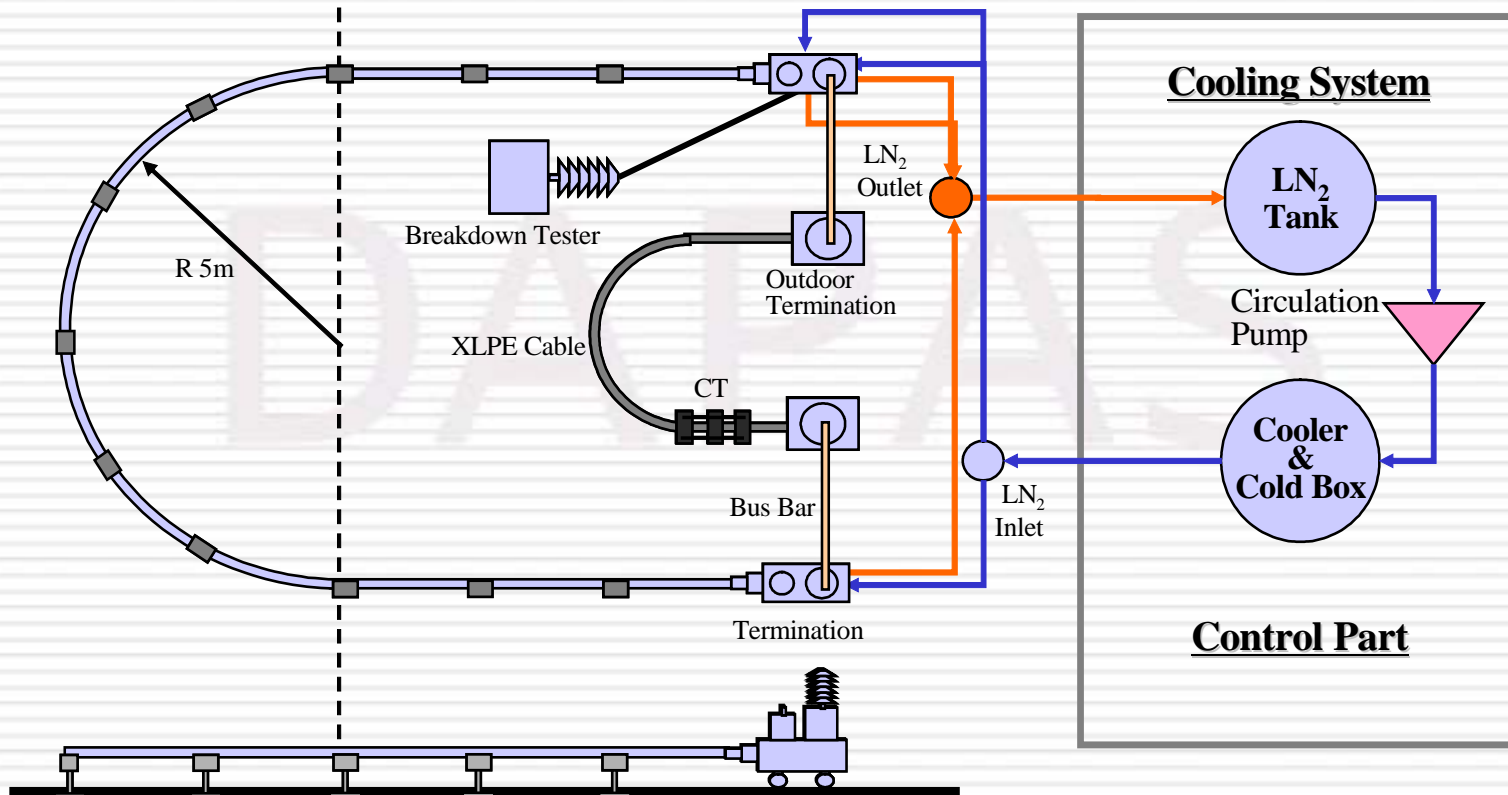
## Specifications of HTS tape

Maker	AMSC
Thickness [mm]	0.3
Width[mm]	4.1
Critical Current @77K,SF	115 [A]

## HTS cable construction details

Number of Layers		3
Winding	Pitch	200 – 500 [mm]
	Direction	+ – +
Dielectric	Type	Cold
	Material	PP Laminated Paper
Cryostat		Aluminum
Total length		30[m]

# Test Field for 1 Phase

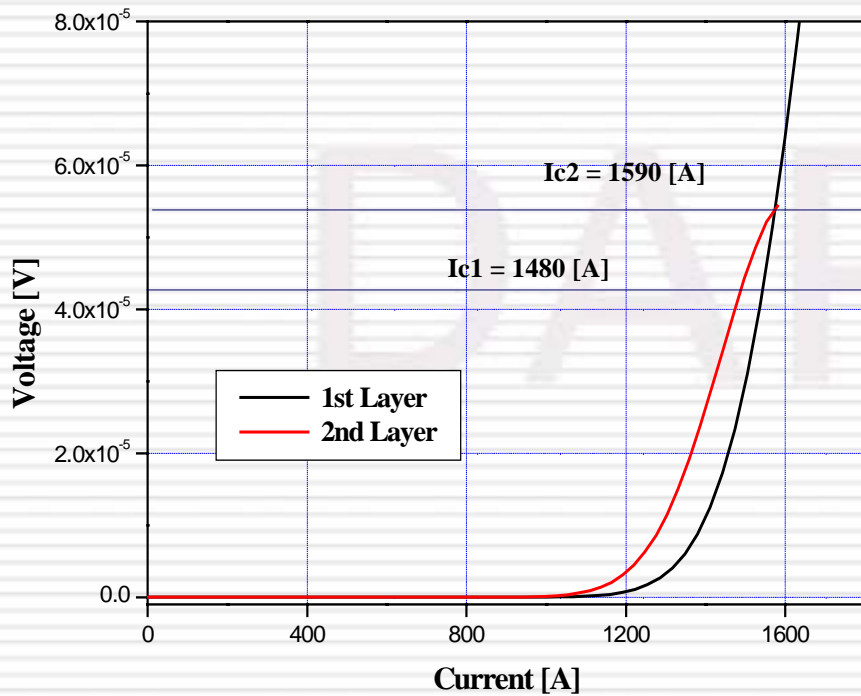


# Test Field for 1 Phase

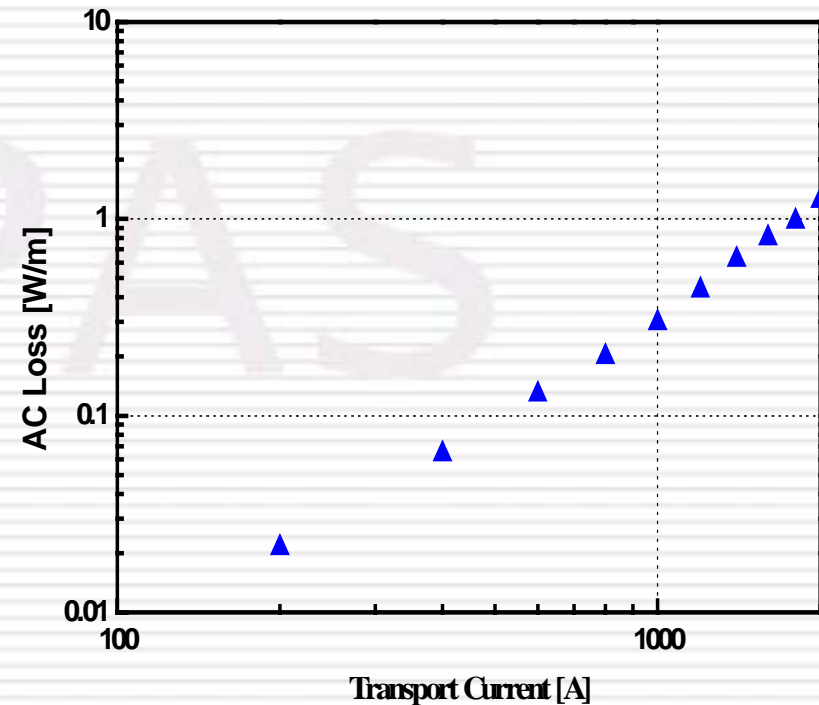


# Test Results of 1 phase

## DC $I_c$ measurements



## AC loss measurements



# 3 Phase Cable

## Specifications of HTS tape

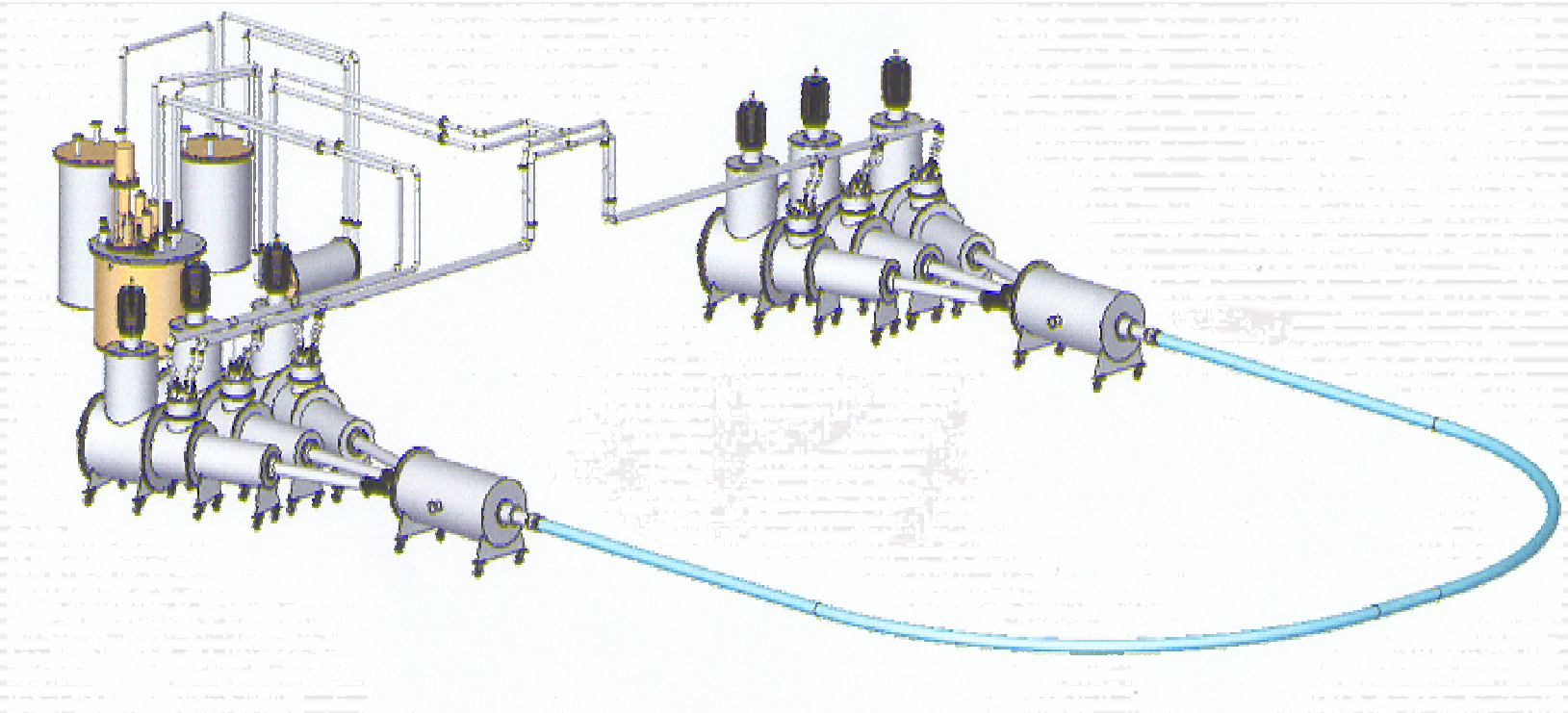


Maker	AMSC	InnoST
Thickness [mm]	0.3	0.23
Width [mm]	4.1	4.2
Critical Current @77K,SF [A]	115	85

## HTS cable construction details

Number of Layers		4
Winding	Pitch	200 – 500 [mm]
	Direction	+ – + –
Dielectric	Type	Cold
	Material	PP Laminated Paper
Cryostat		Aluminum
Total length		30[m]

# Assembled Cooling System (3-phase, 30m)



## ◆ Cable Cooling

- ✓ Cooling Source : Cryocooler

## ◆ Termination Cooling

- ✓ Cooling Source : LN<sub>2</sub> Latent Heat

## ◆ Design Requirements

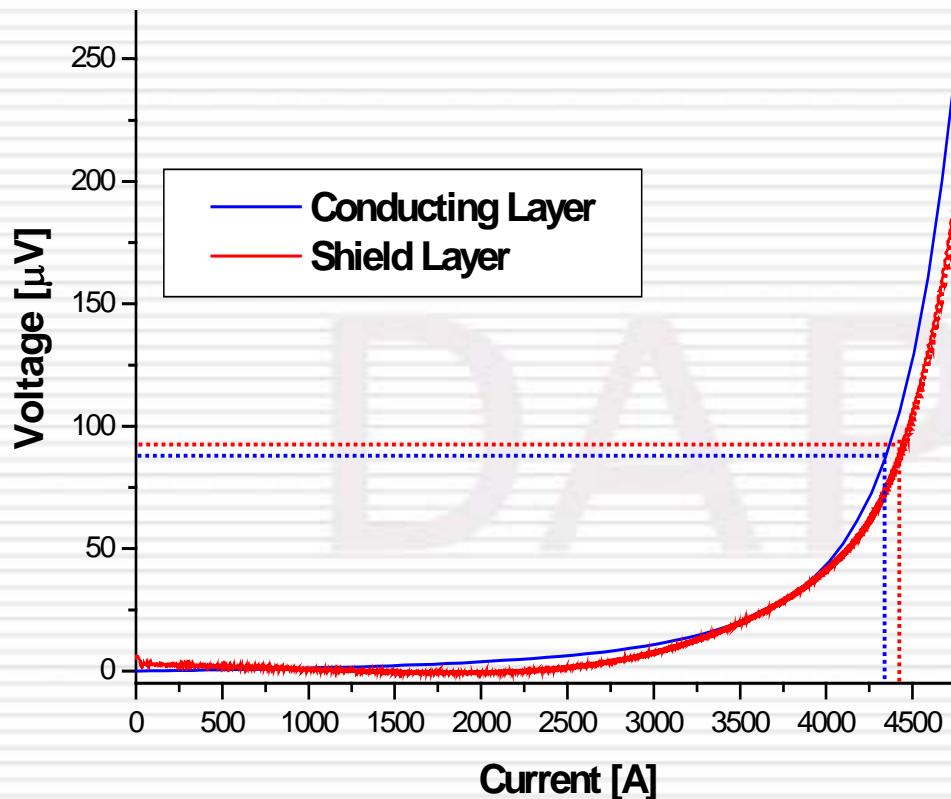
- ✓ Cooling Load : 3,000 W
- ✓ LN<sub>2</sub> Line Pressure : 3 ~ 10 bar
- ✓ LN<sub>2</sub> Flow rate : ~ 0.6 / 0.4 kg/s
- ✓ LN<sub>2</sub> Temperature : 70 ~ 75 / 70 ~ 80K



# 3 Phase HTS Cable System

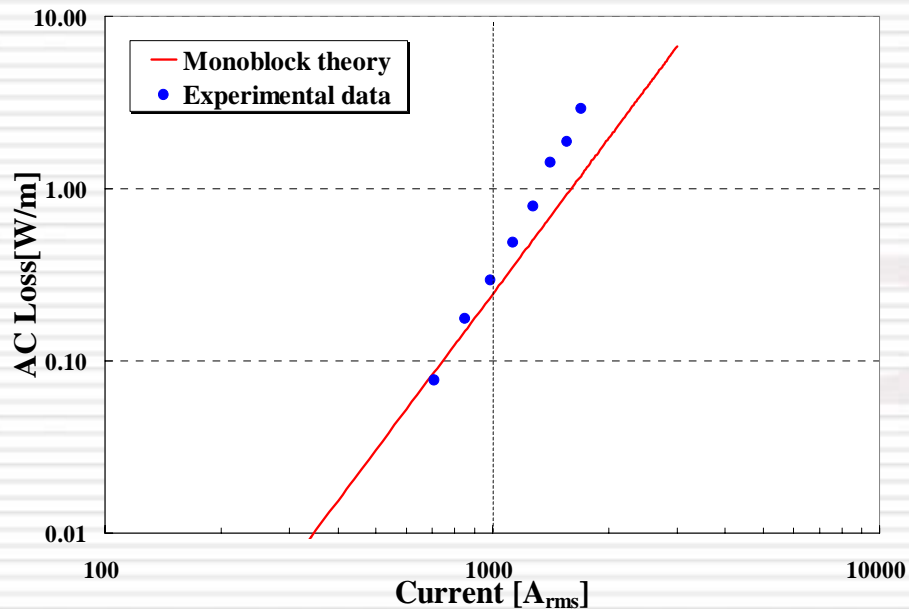


# DC V-I measurements for 3 phase cable

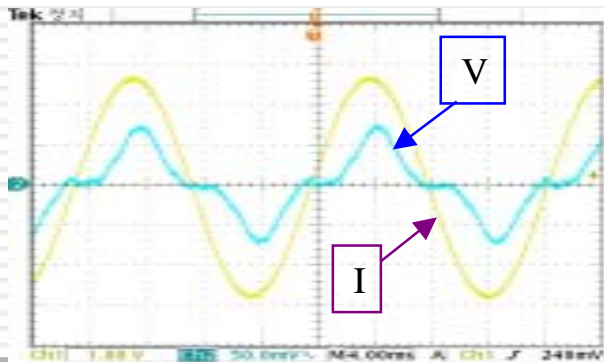


- DC critical current
  - conducting layer : 4370A
  - shield layer : 4400A
- This value is about 2.4 times of AC rating current (1800 Apeak)

# AC loss measurements for 3 phase cable

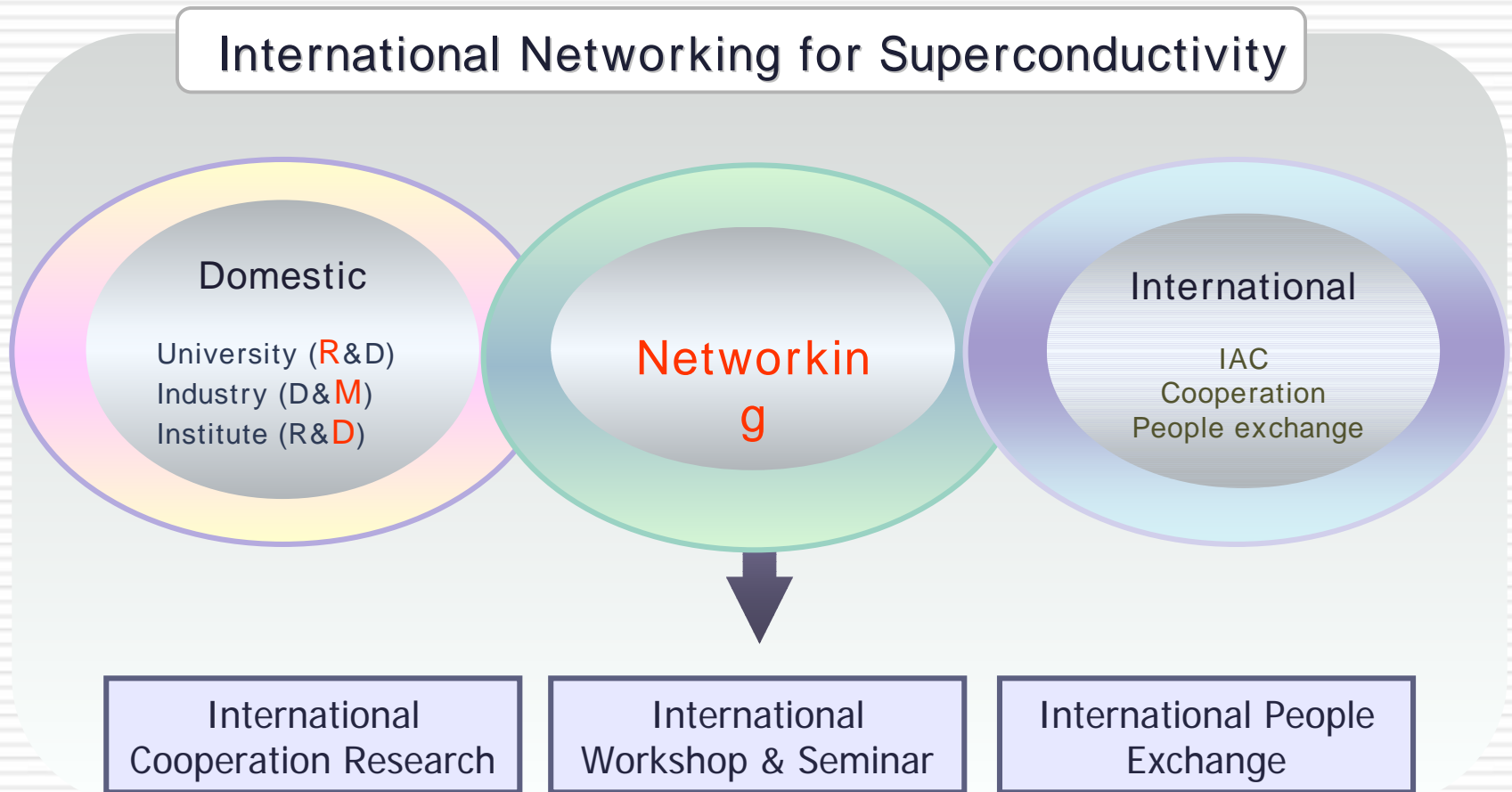


- The ac loss of HTS cable model was measured using direct electrical techniques.
- The measured ac loss data are in good agreement with those calculated by monoblock theory.
- At the operating condition of 1260Arms @ 60Hz, the measured ac losses of HTS cable model is 0.78[W/m]

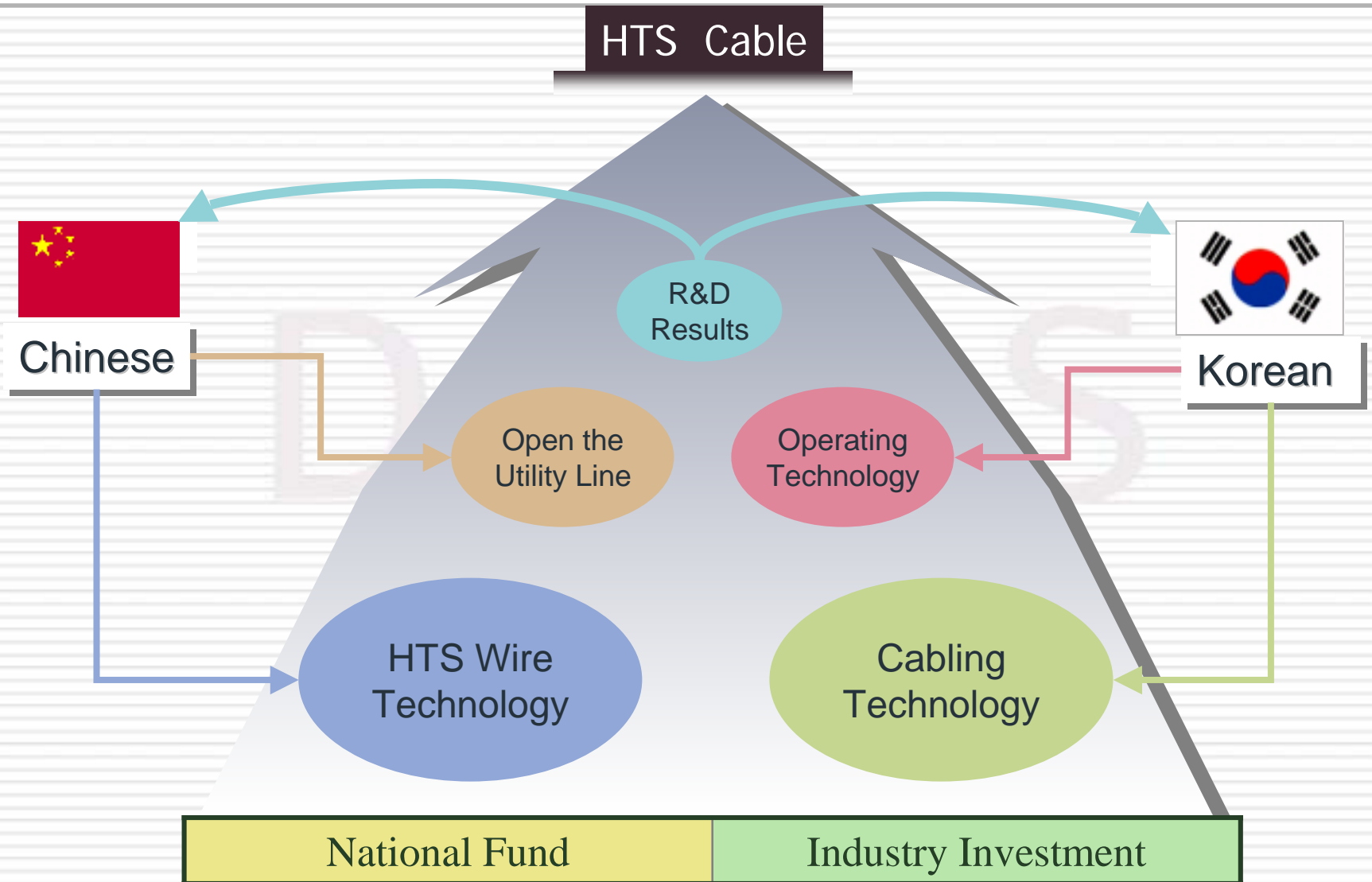


- ❖ Performance test of the 22.9kV/50MVA 30m system
- ❖ Evaluation and commercialization of the HTS Cable system
- ❖ Development of the Transmission Level system
- ❖ Development of the Coated Conductor Cable

# Let us do more about international cooperation.



# International Corporation





Xie Xie  
Thank you

HTS Transmission Power Cable

