KHNP's strategies for

Multi-unit Extreme Hazards Response

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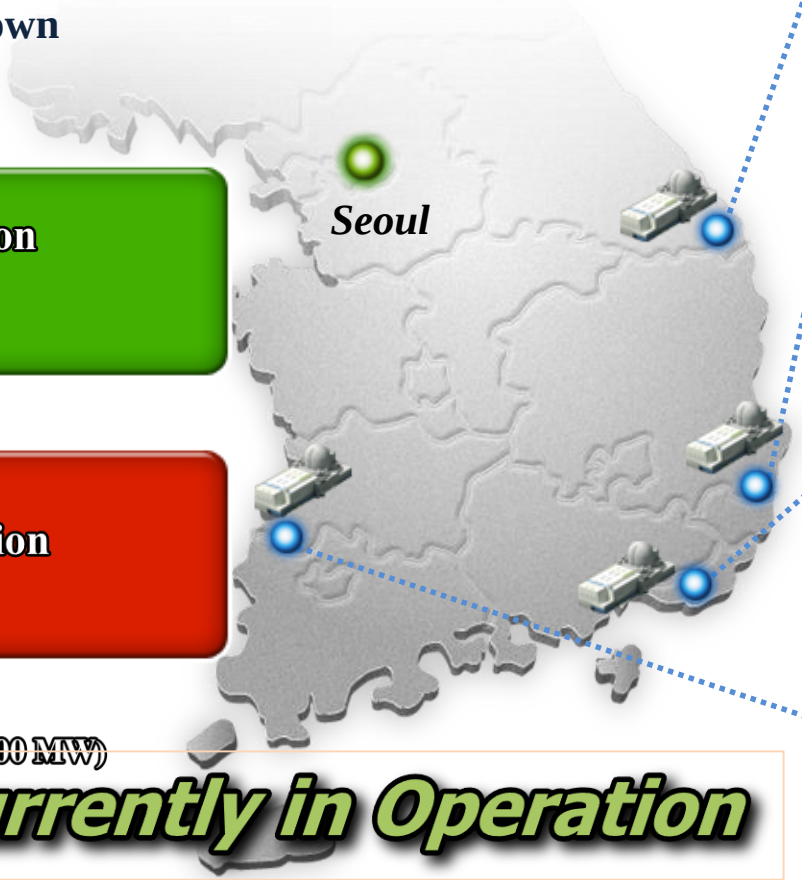
Nuclear Power Program

(As of April 2018)

- In Operation
- Under Construction
- Permanently Shutdown



In operation

24 units

Under Construction

5 units

Planned

4 units (5,600 MW)

24 NPPs Currently in Operation

1. Post Fukushima Safety Measures

Post Fukushima Safety Measures

- '11.3 : Fukushima nuclear accidents
- '11.5 : NSSC, performed "Integrated Safety Review" of all plants
  - ✓ Identified and requested 46 safety improvement action items
  - ✓ KHNP's self-assessment added additional 10 action items
- '13.4 : NSSC, Stress tests for old plants (Wolsong 1, Kori 1)
  Coupled Licensing Renewal of old plants with modified EU ST Spec.
- '14.3 : Critical Safety Improvements(3 items) were supplemented
  - ✓ Evaluation of extreme disaster(natural + Artificial) and SSCs improve.
  - ✓ Expert support system for case of beyond & SA scenarios
  - ✓ Facilities for emergency responses, command & control
- '15.6 : Revised Nuclear Safety law for AMP and ordered ST for all plants
  - ✓ Accident Management Plan(AMP) by 2019.6
  - ✓ Stress Tests(ST) for all operating plants by 2019.12
- '16.3 : KHNP, started the AMP development projects
- '16.6 : NSSC, confirmed government notifications related to AMP

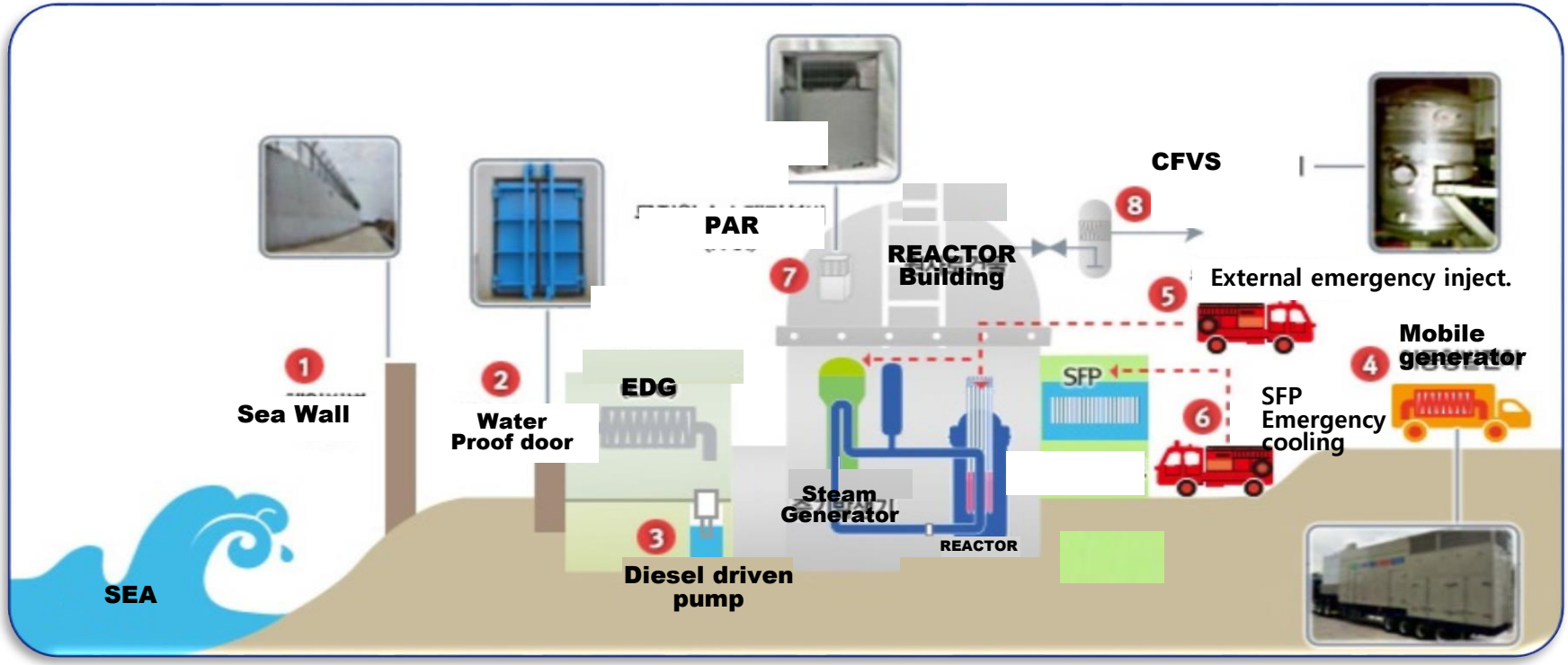
Post Fukushima Safety Measures

11	Additional radiation protective equipment for the sake of residents	Emergency Response
10	Passive hydrogen removal equipment Containment Filtered Vent System	Severe Accident
15	Mobile generator vehicles Primary & secondary external Inj. Direct make-up path to SFP	Electrical Power and Cooling Capability
20	ASTS Sea wall height extension	Earthquake and Tsunami

* ASTS : Automatic Seismic Trip System, SAMG : Severe Accident Management Guideline, SFP : Spent Fuel Pool

Post Fukushima Safety Measures

Major Improvements



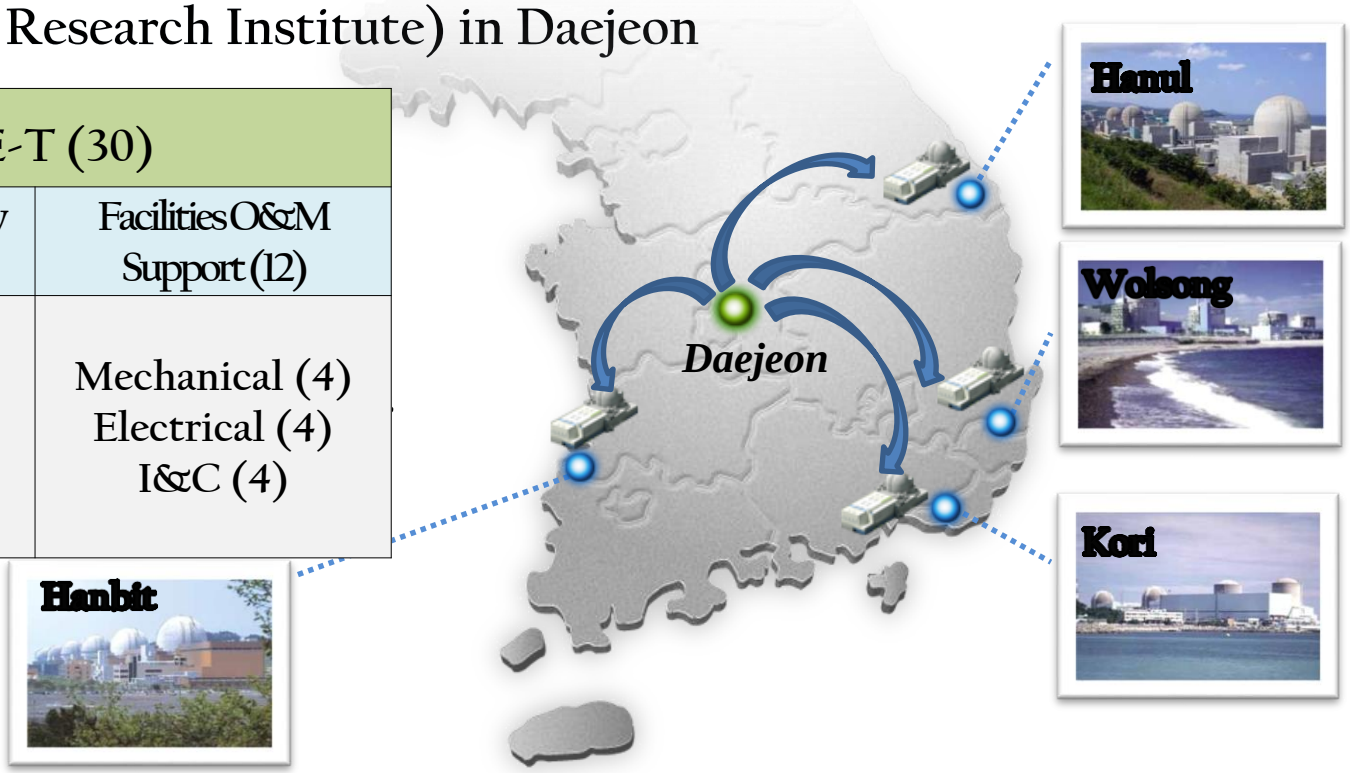
① Height extension of the seawall
② Installation of waterproof doors
③ Installation of waterproof drain pumps
④ Mobile generator vehicles
⑤ Installation of primary/secondary external injection path
⑥ External injection loop for SFP
⑦ Installation of passive hydrogen removal equipment
⑧ Containment Filtered Vent System

Post Fukushima Safety Measures

Centralized expert team and center

- SAFE-T : Severe Accident Fast Response Expert Team
- Can be dispatched to the emergency site within 6 Hr from the KHNP CRI (Central Research Institute) in Daejeon

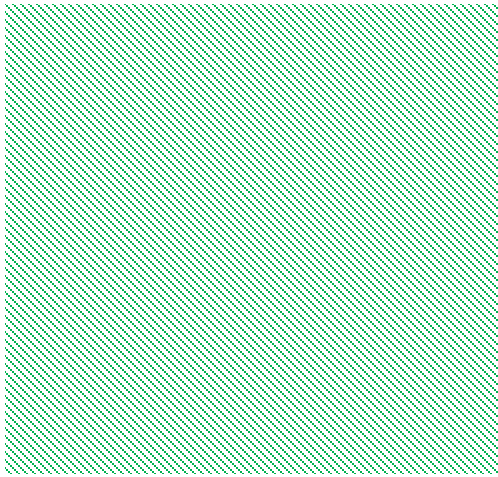
SAFE-T (30)	
Accident Strategy Support (16)	Facilities O&M Support (12)
WEC Type (4) OPR1000 (4) CANDU (4) APR1400 (2) Framatone (2)	Mechanical (4) Electrical (4) I&C (4)



Emergency response center : Seismic Safety Degree 0.5g

- To reinforce the accident response command and control

2. Stress Tests



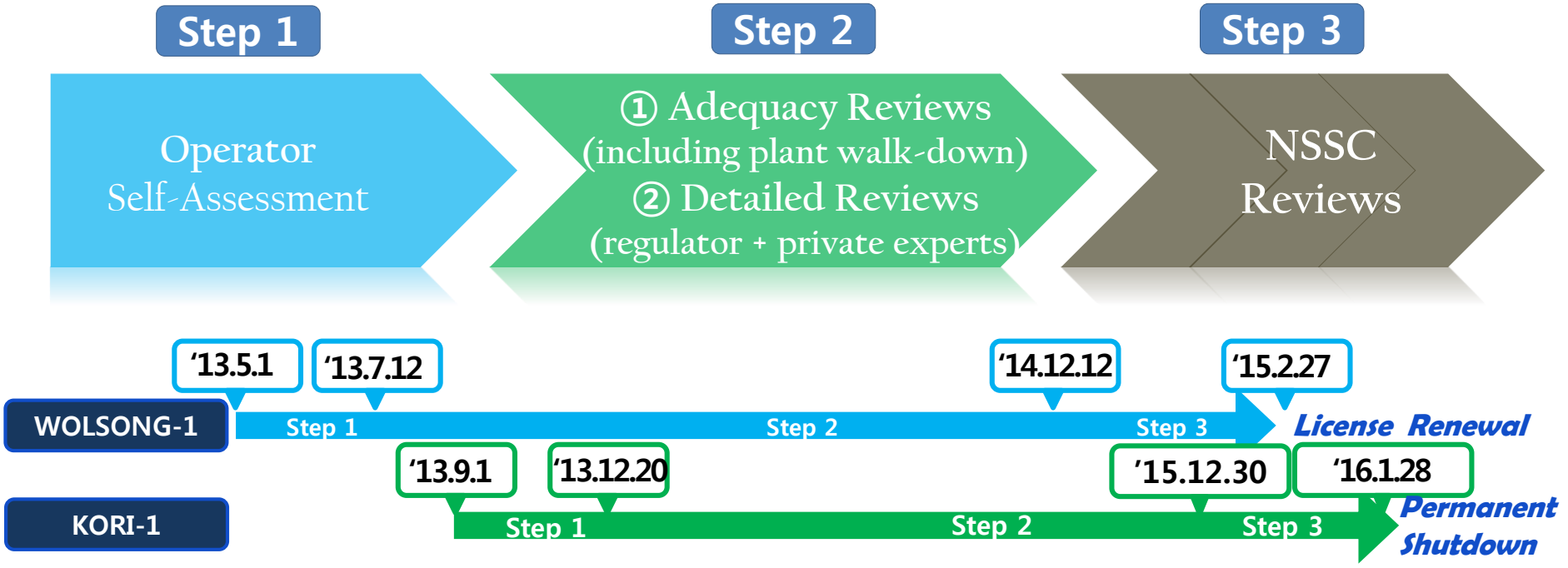
Stress Tests for old plants

Areas

①Earthquake ②Tsunami ③Loss of Safety Functions (SBO +LUHS) ④Severe accident Management ⑤Emergency res.

Guideline

Stress Tests Specifications of NSSC (2013.04.30)



Stress Tests for old plants

Wolsong Unit 1

- ✓ **10 year extension of operational permission**
- ✓ **19 safety improvement actions items identified**
  - ✓ (Natural Hazards) 3 items
  - ✓ (Safety Function Failure) 3 items
  - ✓ (Severe Accident) 7 items
  - ✓ (Emergency response) 6 items

Kori Unit 1

- ✓ **Permanently shutdown**
- ✓ **14 safety improvement actions items identified**
  - ✓ (Natural Hazards) 2 items
  - ✓ (Safety Function Failure) 3 items
  - ✓ (Severe Accident) 1 items
  - ✓ (Emergency response) 8 items

Stress Tests for All Operational NPPs

Background

- NSSC decided to re-evaluate all existing NPP safety applying ST spec. ('15.09.24)
- NSSC confirmed Stress Tests Specification ('16.10.27)
- KHNP submitted Stress Tests implementation plan ('16.11.11)

Contents

Area 1

Characteristics of extreme natural events exceeding the design basis

-Earthquake, flooding, tsunami and storm surge

※ Return period of 10,000 years

Area 2

SSCs Integrity against extreme natural events

-Earthquake, internal flooding, internal fire, etc.

Area 3

Plant's capability to cope with the loss of safety functions

- Essential coping equipment identification
- Plant response to loss of all AC power and UHS (Scenario 1-6)
- Plant response to above scenario accompanying extreme natural events (Scenario 7-9)

Area 4

Severe accident management

-Core cooling, containment integrity prevention capability evaluation

-SPF shielding and cooling capability evaluation

Area 5

Emergency preparedness and response

-Emergency response capability evaluation

-Decision making adequacy evaluation

-Emergency response facility habitability evaluation

Newly added

Area 6

Evaluation of accident coping capability

-Accident management strategies, operators' action, off-site resources, procedures, education and training, human factors engineering evaluation, multi-unit accident response capability evaluation

Stress Tests for All Operational NPPs

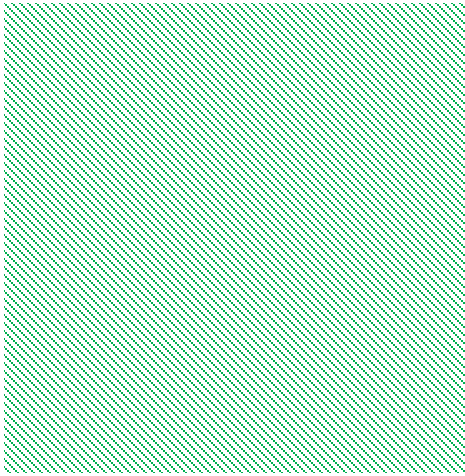
1st Step : Assessment of representative reactors (by JUN 2018)

- Divided into 5 Reactor Types out of 24 nuclear plants in operation
- Westinghouse 2-loop, 3-loop, CANDU, Framatom, OPR 1000 (Optimized Power Reactor)

2nd Step : Assessment of the rest NPPs (by JUN 2019)

- Gap analysis between the representative reactors and the rest
- First step results will be incorporated to the rest nuclear power plants

3. Integrated Accident Management Plan

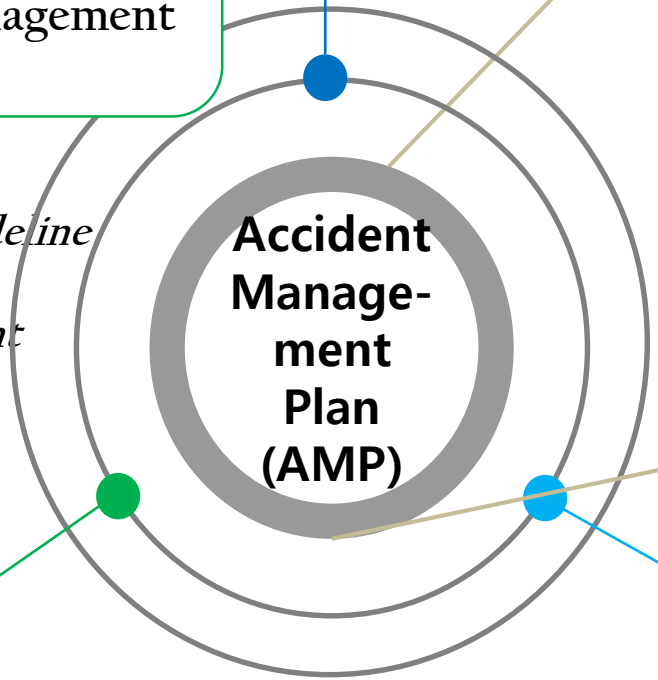


Meaning of AMP

- ✓ Nuclear law revision (Jun 2016)
  "...all operating NPPs should submit accident management plans..."
- ✓ Schedule : Jan 2017 - Jun 2019
- ✓ The legal document for the integrated accident management from DBA to SA

MOG : MACST Operating Guideline

MACST : Multi-barrier Accident Coping STrategy



EOP

DBA management

AMP Contents

- ✓ AMP Strategies & Equipments Accident Management
- ✓ Implementation Structure
- ✓ AM Capability Evaluation
- ✓ Emergency Operating Procedure Guideline
- ✓ Extreme Disaster Mitigation Guideline
- ✓ Severe Accident Mitigation Guideline
- ✓ AM Education & Training Plan

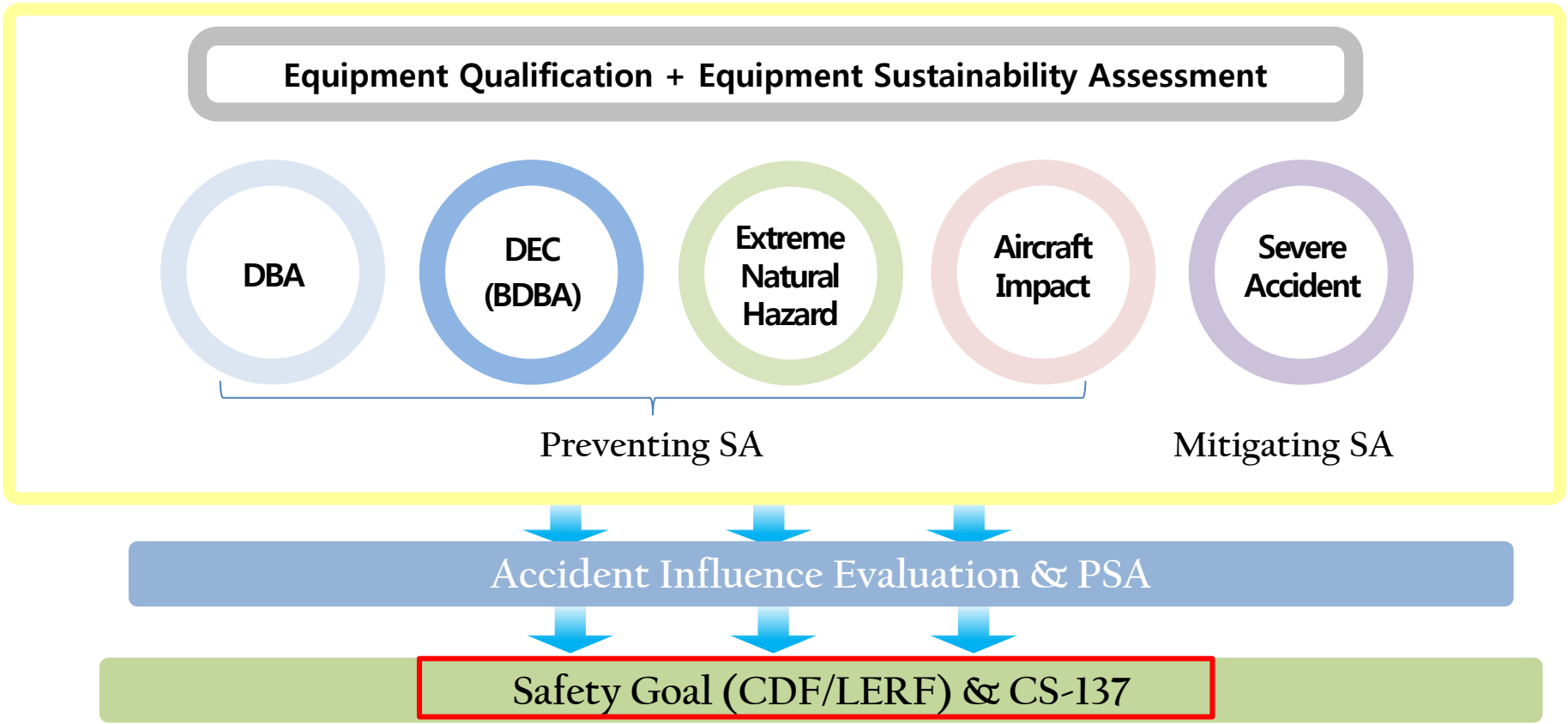
Extreme Hazard management

MOG/ EDMG

SAMG

Severe Accident Management

Structure of AMP



Risk Matrix	Severe Accident Policy Statement (Order, '01)	Accident Management Plan (Law, '16)
PSA Level 1 Core Damage Frequency(CDF)	‹ 1.0E-4	‹ 1.0E-4 (0.1 for New plants)
PSA Level 2 Large Early Release Frequency(LERF)	‹ 1.0E-5	‹ 1.0E-5 (0.1 for New plants)
Cs-137 100TBq Release	-	‹1.0E-6

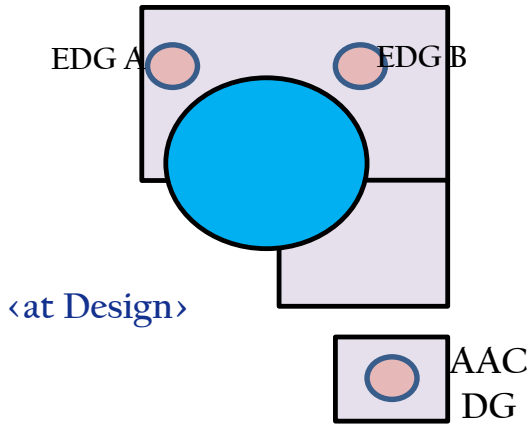
Strategies for AMP & Added Facilities

- Main Target Event : (Site Common) ELAP, LUHS
  - ELAP : Extended Loss of AC Power
  - LUHS : Loss of Ultimate Heat Sink
- Establish a defense-in-depth severe-accident preventing & mitigating (coping) strategy
- 3-Phases Strategy: use of installed(Phase 1), onsite portable (Phase 2) and offsite supplemental resources(Phase 3)

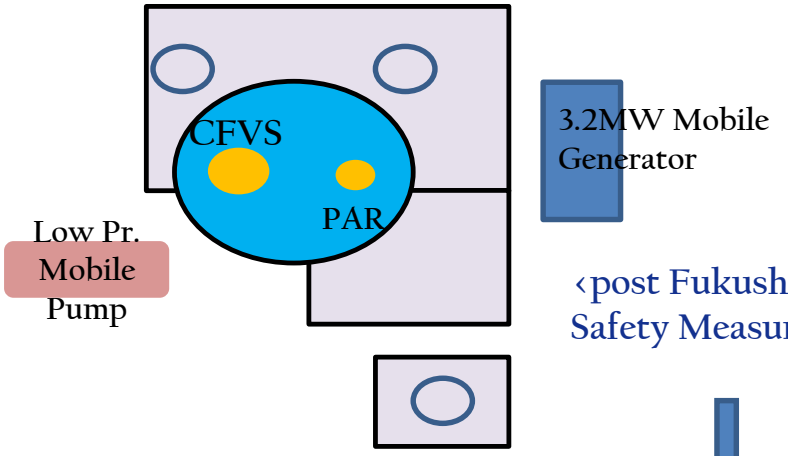
Phase	Equipment	Example
Phase 1 (0 - 8hr)	Installed equipment **	EP : Battery(extension) CW : Turbine Driven AFWP
Phase 2 (- 72hr)	Onsite Portable Equipment * SAFE-T	EP : Mobile DG (4.16 kV, 1 MW) CW : Small & Medium Mobile Pump
Phase 3 (72hr -)	Offsite Equipment * SAFE-T + Outside support	EP : Mobile DG(4.16kV, 3.2MW) CW : Large Mobile Pump High Capacity Spray Pump

** Shift Operation Staff supplemented by additional EOF onsite staff

Strategies for AMP & Added Facilities



‹at Design›

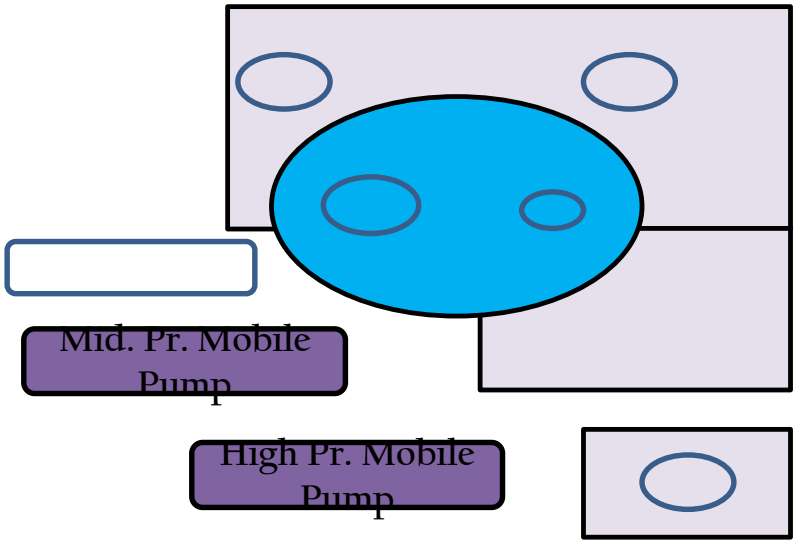


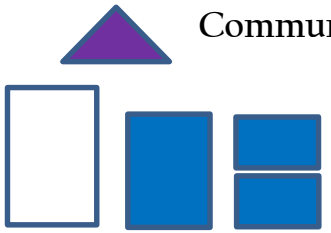
‹post Fukushima
Safety Measures›

High flow Mobile Pump

Mobile Heat Exchanger

Mobile Purifi. Facility





Communication Equipment

Portable generator

1MW
Mobile generator

‹AMP &ST for
Multi Unit Hazards›

High Pr. Spray Equipment

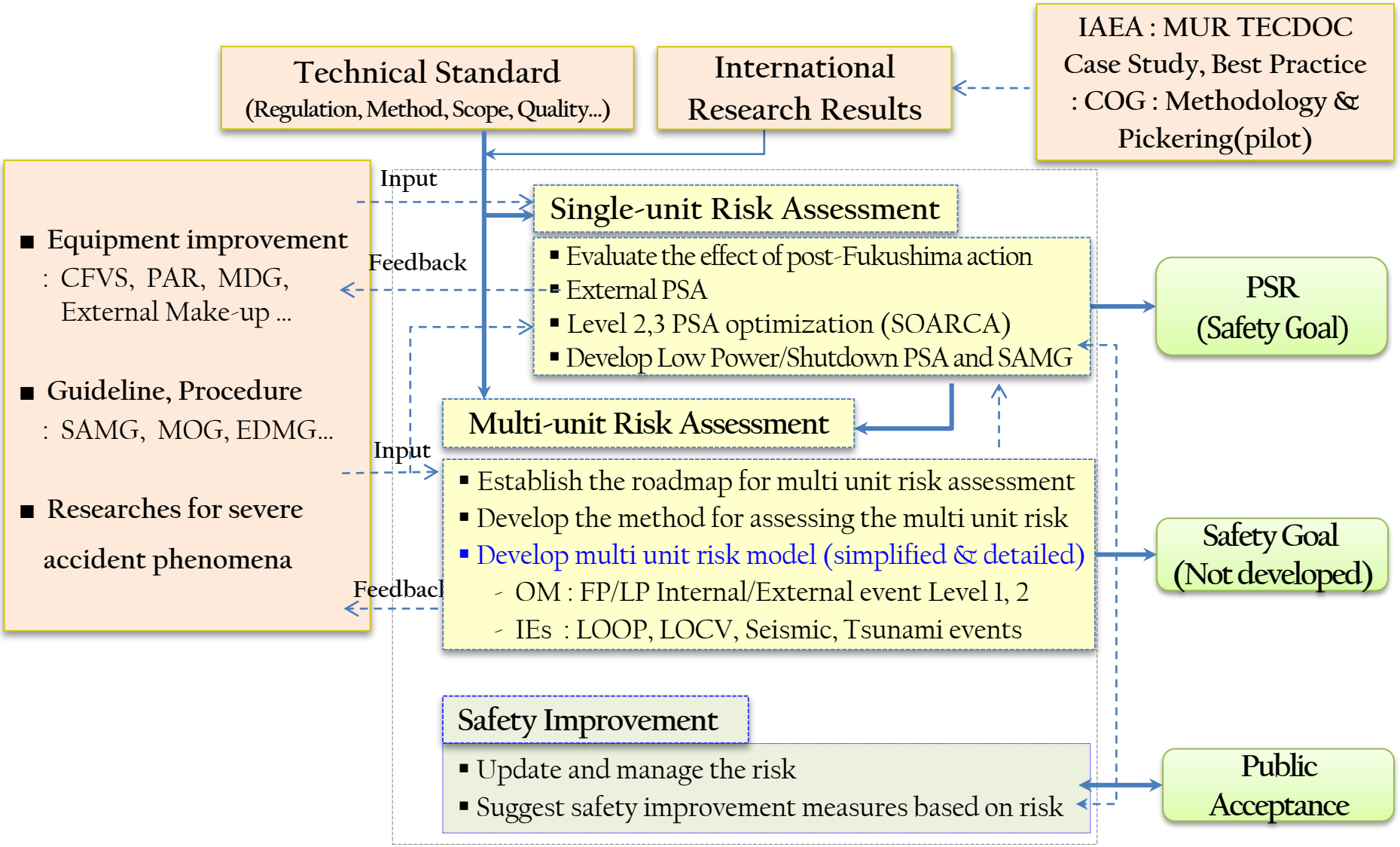
Multi-unit(Site) Risk Analyses

- Issuing MUPSA in Korea
  - ✓ After Fukushima, multi-unit accident was highlighted in Korea
  - ✓ Another ways to cope the multi-unit extreme disasters by probabilistic means
  - ✓ Issued in the **Operating Licensing** process of Shin-Kori 3 (Oct. 2015)
  - ✓ Issued in the **Construction Licensing** process of Shin-Kori 5&6 (Jun. 2016)

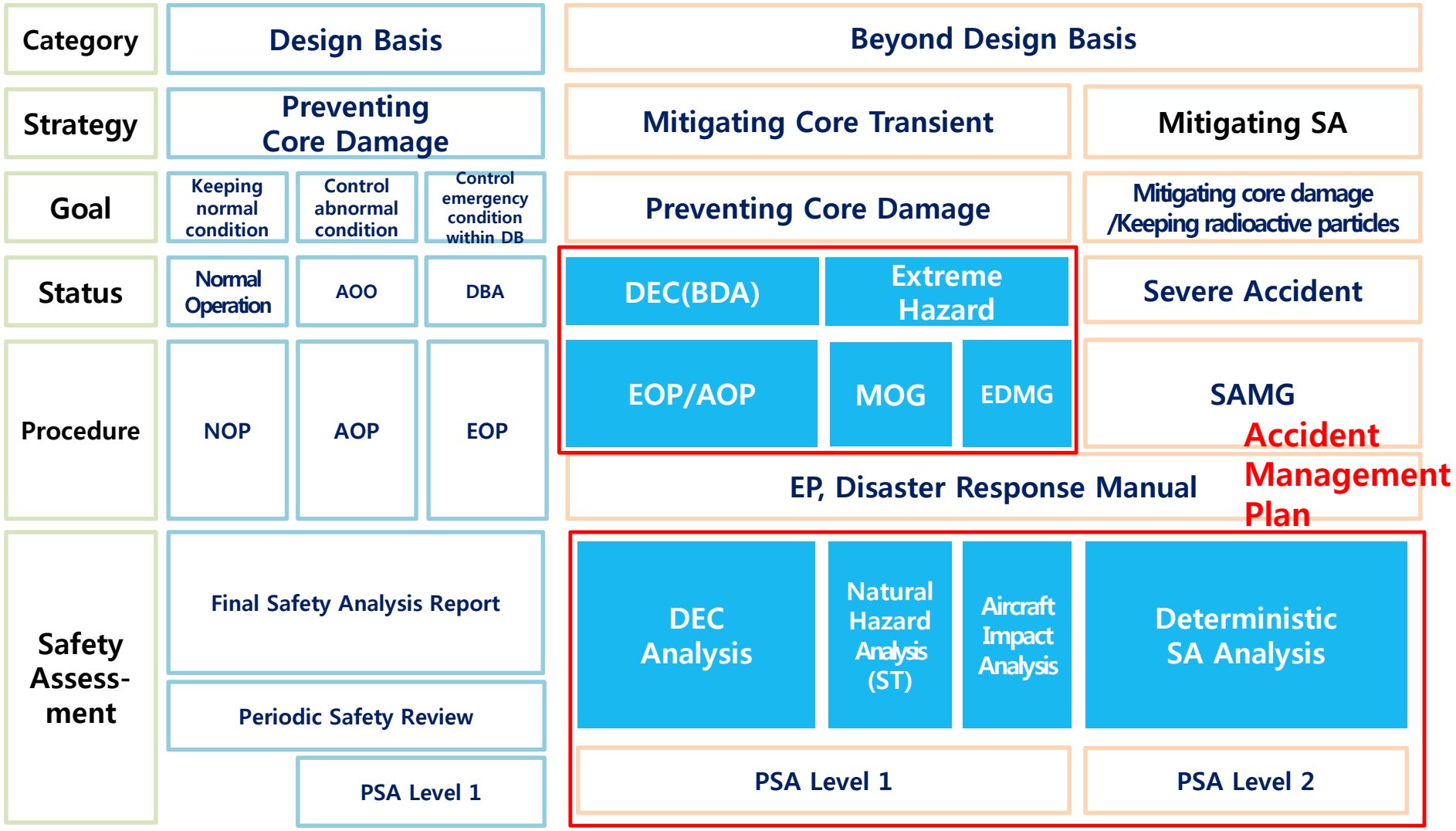
How to establish
Korean specific MUR Methodology/Safety Goal?

- **Post actions for the issues**
  - ✓ **NSSC** (Nuclear Safety & Security Commission) launched the project to set up regulatory requirements for MUPSA by the end of 2021
  - ✓ **KHNP** started the project to develop methodology and pilot MUPSA model for Kori Site (six units in operation and three units in construction)
    - ✓ **Preliminary assessment** will be done by **Jun. of 2018**
    - ✓ **Final assessment** will be done by **Jun. of 2020**

Multi-unit(Site) Risk Analyses



Development effect of AMP



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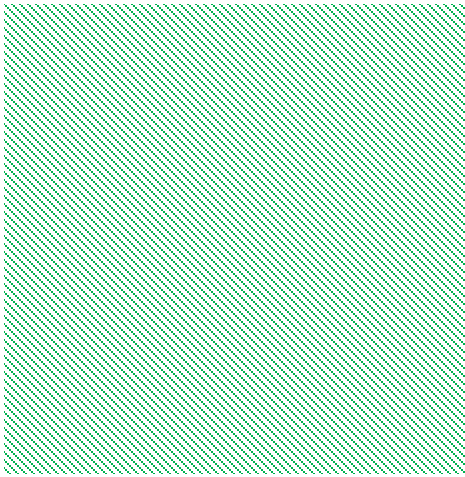
Safety Objectives of PFA, ST, AMP



Safety Objectives

Post Fukushima Safety Review	Prompt Remedy to SSC	✓ Ensuring Coping Capability against Extreme Natural Hazards ✓ Regulatory body-University-Research Institute Collaboration ✓ Short Period Evaluation (21 Mar. 2011 – 30 Apr. 2011)
Stress Tests	Applying European Standard	✓ Introduced as one of presidential election pledge (2013) ✓ Modified EU Stress tests Specification ✓ First Application : License Renewal Plant (Kori-1, Wolsong1) ✓ Extended to all NPPs : Total 22 units (Sep. 2015 – June 2019)
Accident Management Plan	Establishing Integrated Accident Management System	✓ Nuclear Law Revision (June 2016) : "All operating NPPs should submit accident management plan by 2019.6" ✓ Include DBA, BDBA (Extreme Natural Hazards + Air Craft Impact), Severe accident management Strategies ✓ Accident management strategy effectiveness assessment and Safety goal achievement * Mandatory Requirements

Safety Objective of (AMP + ST)

[● Complete ◐ ongoing ○ Planning]

Classif-ed	Regulatory Status		Industry Actions						
			Strategies and Assessment				Equipment		
	Stress Test	BDBEE Legalization	Natural Hazard Assessment	Man-induced Hazard Assessment	Severe Accident Prevention Strategies	Severe Accident Emergency Response Organization	Natural Hazard	Severe Accident Prevention	Severe Accident Mitigation
USA		◐	●	●	●	●	●	●	●
Japan	●	●	●	●	●		●	◐	◐
France	●		●	◐	●	●	●	◐	◐
Korea	◐	●	◐	◐	◐	●	●	◐	◐

Overall, we are implementing world-class post Fukushima actions,
but we need to reinforce the prevention of severe accidents and establish concrete strategies

Safety Objective of (AMP + ST)

Stress Test ('17. 2 ~ '19. 12)

AMP ('17.1 ~ '19.6)

Classi-fied	Regulatory Status		Industry Actions						
			Strategies and Assessment				Equipment		
	Stress Test	BDBEE Legalization	Natural Hazard Assessment	Man-induced Hazard Assessment	Severe Accident Prevention Strategies	Severe Accident Emergency Response Organization	Natural Hazard	Severe Accident Prevention	Severe Accident Mitigation
Korea	●	●	●	●	●	●	●	●	●

AMP+ ST = Ensure the World-class Safety by Integrating the Advantages of each country

USA
FLEX strategies by Phase 1/2/3
Severe Accident Prevention Strategies by Mobile Equipment

+

France
Stress Test conduction for All NPPs
Off-site support by severe accident emergency response organization

+

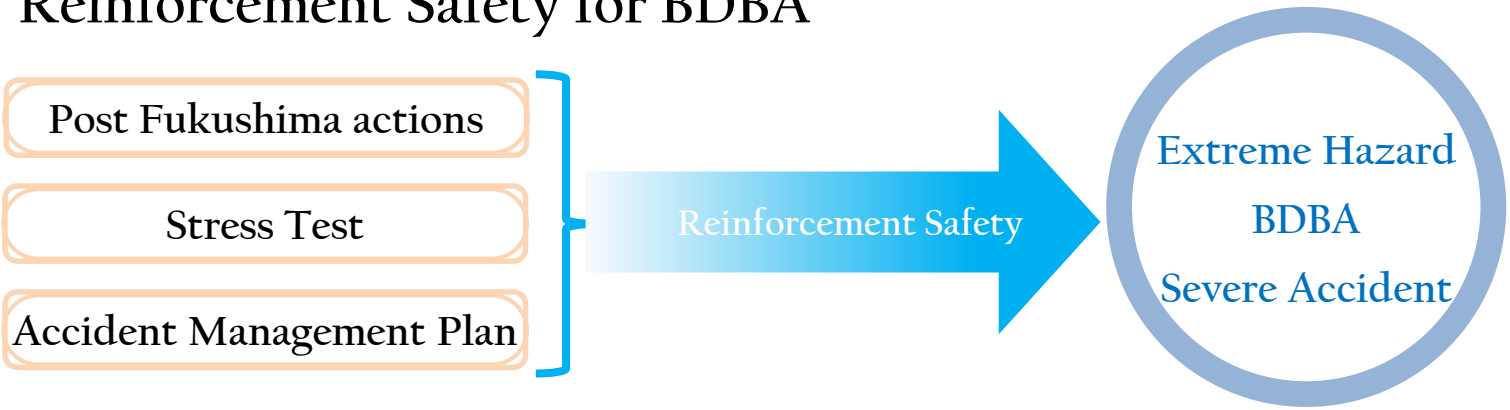
Japan
Legalization of reinforcement of the facility for the accident
Conservative approach of selecting the accident equipment and strategies

Safety Objective of (AMP + ST)

- Comprehensive response capability against nuclear accident

Improve Installed Equipment + Add Mobile Equipment + Secure Operating Capability + Extend the scope from unit to site

- Reinforcement Safety for BDBA



-
  - Secure the national consensus about Periodic Safety Review, Safety of Life Cycles, ETC.
  - Establish infrastructure and specific systems for Safety

Thank You!
(Q&A)