CONCEPT OF DEFENCE-IN-DEPTH AGAINST EXTERNAL EVENTS IN JAPAN

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After the Fukushima Daiichi accident, new regulatory requirements based on the lessons learned from the Fukushima Daiichi accident were issued and has been applied in the licensing of existing reactors in Japan. However, the concept of defence-in-depth against external events does not seem to become clear in the new regulatory requirements. In this paper we propose an idea of the Defence-in-Depth concept against external events.

I. INTRODUCTION

Japan Nuclear Safety Institute (JANSI) has been established after the Fukushima Daiichi accident as a new entity that can serve as a powerful industry driver and also has autonomy of making judgments unaffected by the intentions of nuclear operators. Based on our sophisticated knowledge and experience, we are finding out the useful information among a wide variety of overflowed information in Japan in order to develop the evaluation methods of defence-in-depth. As a group of experts independent from nuclear operators, JANSI evaluates safety improvement measures from advanced and broader perspectives, and play the powerful function of extending proposals and/or recommendations to nuclear operators, while working in coordination with related organizations in and outside Japan.

One of the most important specific areas of operation that JANSI undertakes is to gather and analyze the latest information in and outside Japan, and provide evaluations, proposals, recommendations and assistance for operators to raise their nuclear safety level so that each operator can pursue initiatives. Although JANSI has mainly been focusing on the assessment of defence-in-depth against severe accidents (accidents causing severe core damage beyond design basis), the scope should be expanded to include the assessment of defence-in-depth against external events. (Ref. 1)

Therefore, we propose an idea of the Defence-in-Depth concept against external events as a first step.

II. ACTION PLAN

We are making an effort to develop the evaluation methods of defence-in-depth against external events, according to the following steps, as shown in Figure-1.

(1) Step-1: Propose the Defence-in-Depth concept against external events
(2) Step-2: Propose a renewal of the related ‘objective trees’ which are described in SRS-46. (Ref. 2)
(3) Step-3: Participate in international cooperation under the IAEA framework
(4) Step-4: Evaluate Japan’s Nuclear Power Station

'Objective tree' in SRS-46 is a graphical depiction with respect to “Structure for defence in depth provisions at each level of defence” as shown in Figure-2. An example of objective tree is also shown in Figure-3.

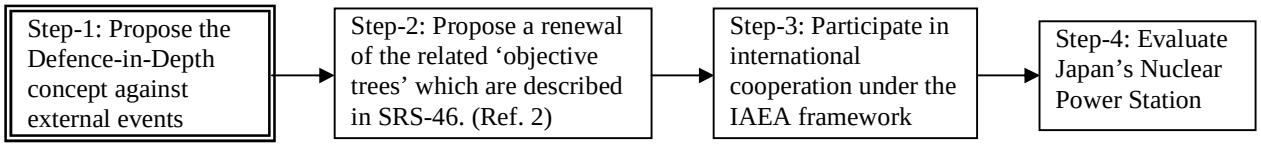
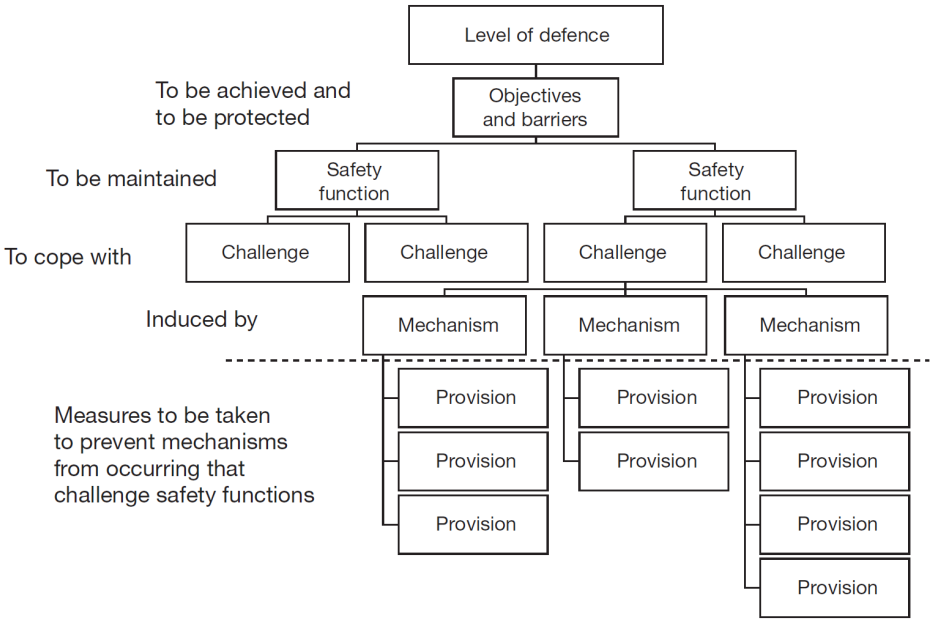
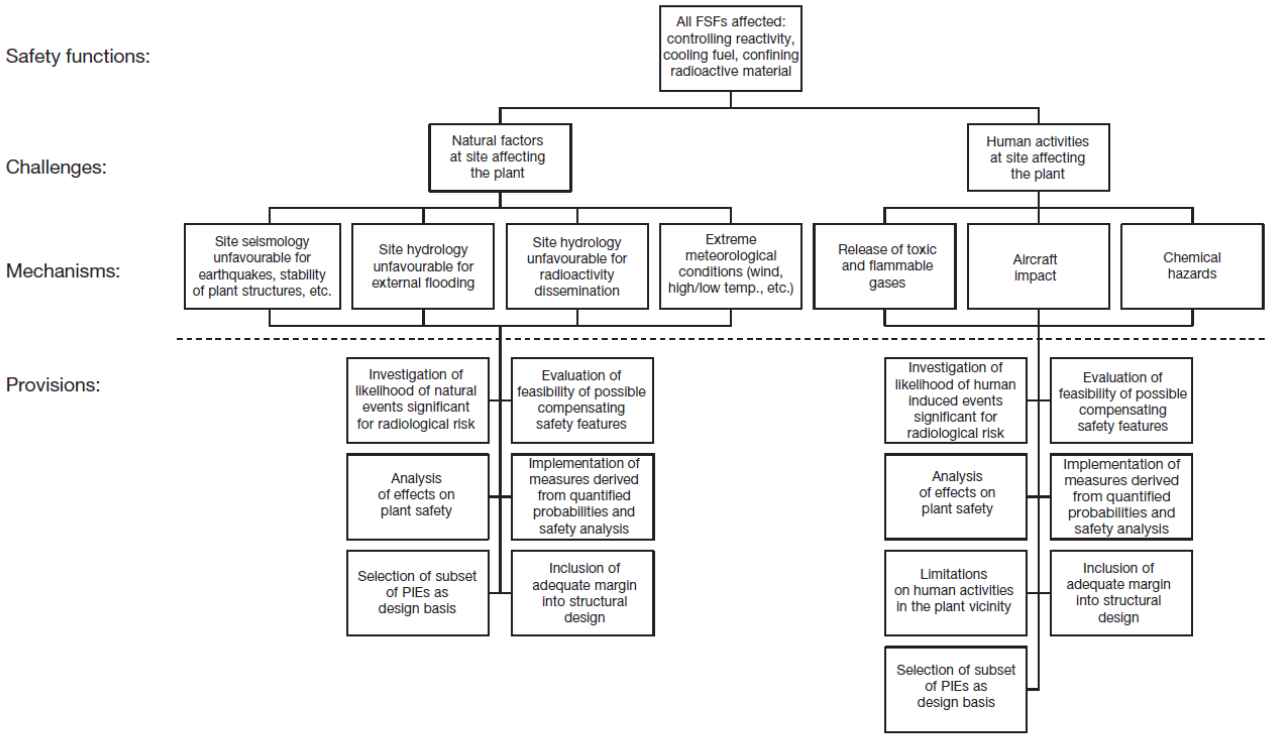


Figure-1: Action plan for developing the evaluation methods of defence-in-depth against external events



Structure for defence in depth provisions at each level of defence.

Figure-2: Concept of 'objective tree' (Ref. 2)



Objective tree for Level 1 of defence in depth (PIE, postulated initiating event). Safety principle (136): external factors affecting the plant.

Figure-3: Example of 'objective tree' (Ref. 2)

III. NEW REGULATORY REQUIREMENTS RELATED TO THE DEFENCE-IN-DEPTH CONCEPT

According to Nuclear Regulation Authority (NRA), the following policy related to the defence-in-depth concept is applied to the new regulatory requirements, and the structure of new requirements is shown in Figure-4. (Ref. 3)

(1) Place emphasis on Defence-in-Depth concept
- Prepare multi-layered protective measures and, for each layer, achieve the objective only in that layer regardless of the measures in the other layers.

(2) Eliminate common cause failures
- Introduce accurate approaches in assessment of earthquake and tsunami and measures against tsunami inundation.
- Introduce assessment of volcano, tornado, & forest fire.
- Enhance measures against fire, internal flooding, & loss of power.
- Make much account of “diversity” and “independence”.

(3) Prepare multi-layered protection against severe accidents

(4) Introduce measures against terrorism

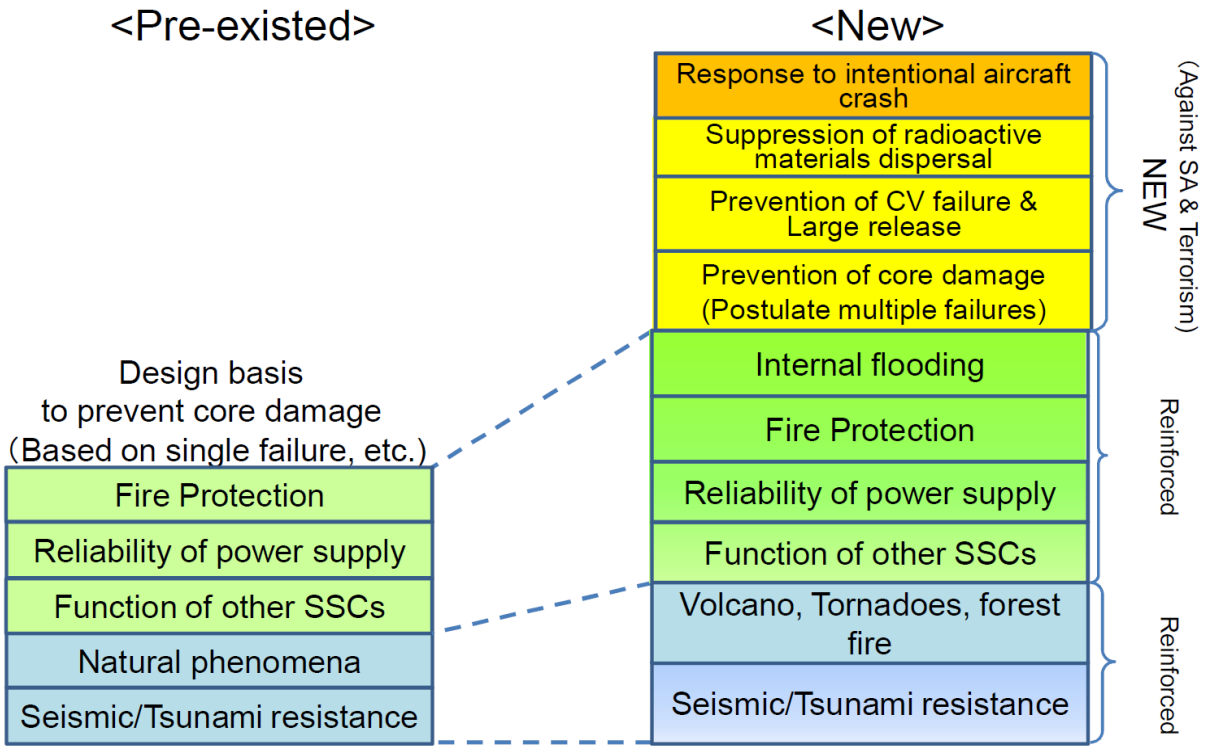


Figure-4: Structure of New Requirements (Ref. 3)

IV. SAFETY IMPROVEMENT ACTIVITIES OF JAPANESE NUCLEAR OPERATORS

According to the Federation of Electric Power Companies of Japan (FEPC), as shown in Figure-5, -6, -7, -8, all the Japanese nuclear operators have been implementing extensive safety improvement activities including the measures against earthquake, tsunami, and severer accidents. (Ref. 4)

Although all the explanations described in Figure-5, -6, -7, -8 were originally written in Japanese, JANSI has translated them into English by its responsibility.

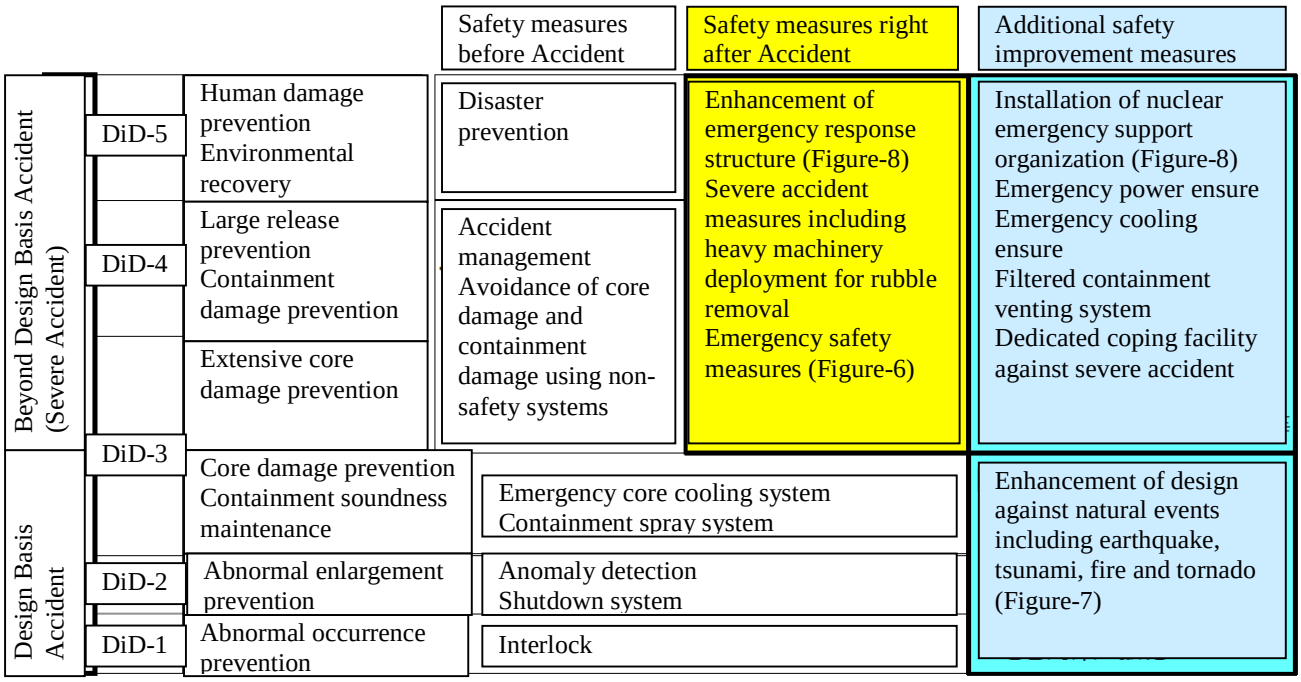


Figure-5: Overview of Safety Improvement Activities of Japanese Nuclear Operators (Ref. 4)[1]

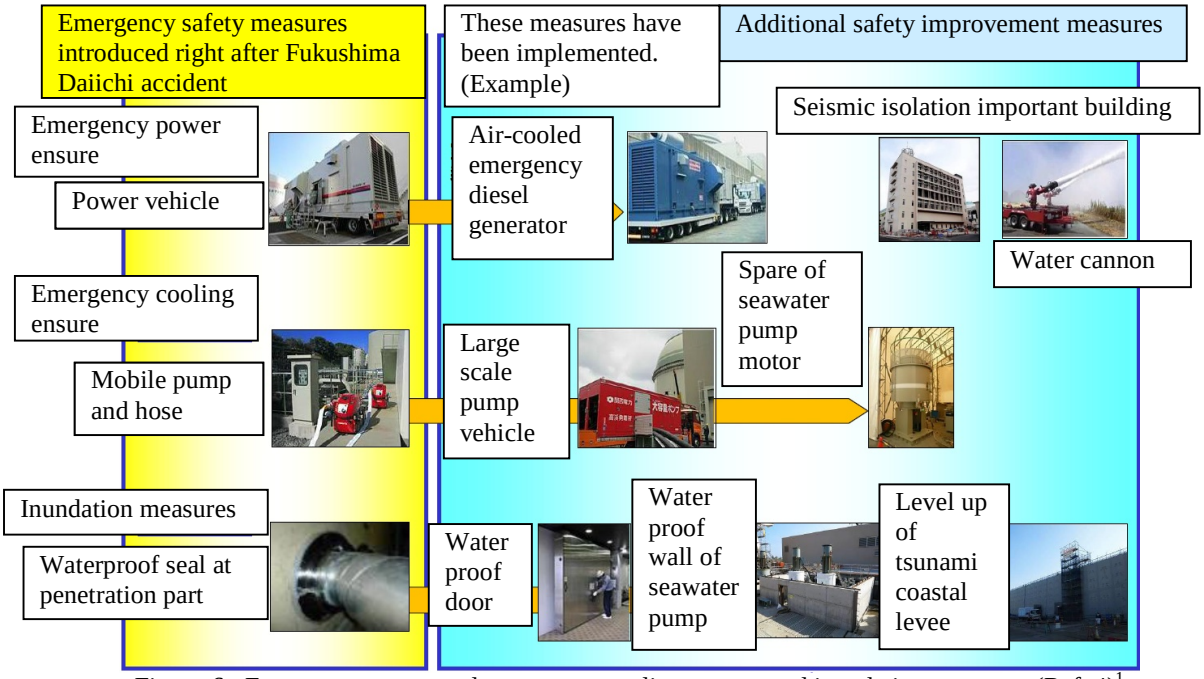


Figure-6: Emergency power and emergency cooling ensure, and inundation measures (Ref. 4)[1]

1 Although all the explanations described in Figure-5, -6 were originally written in Japanese, JANSI has translated them into English by its responsibility.

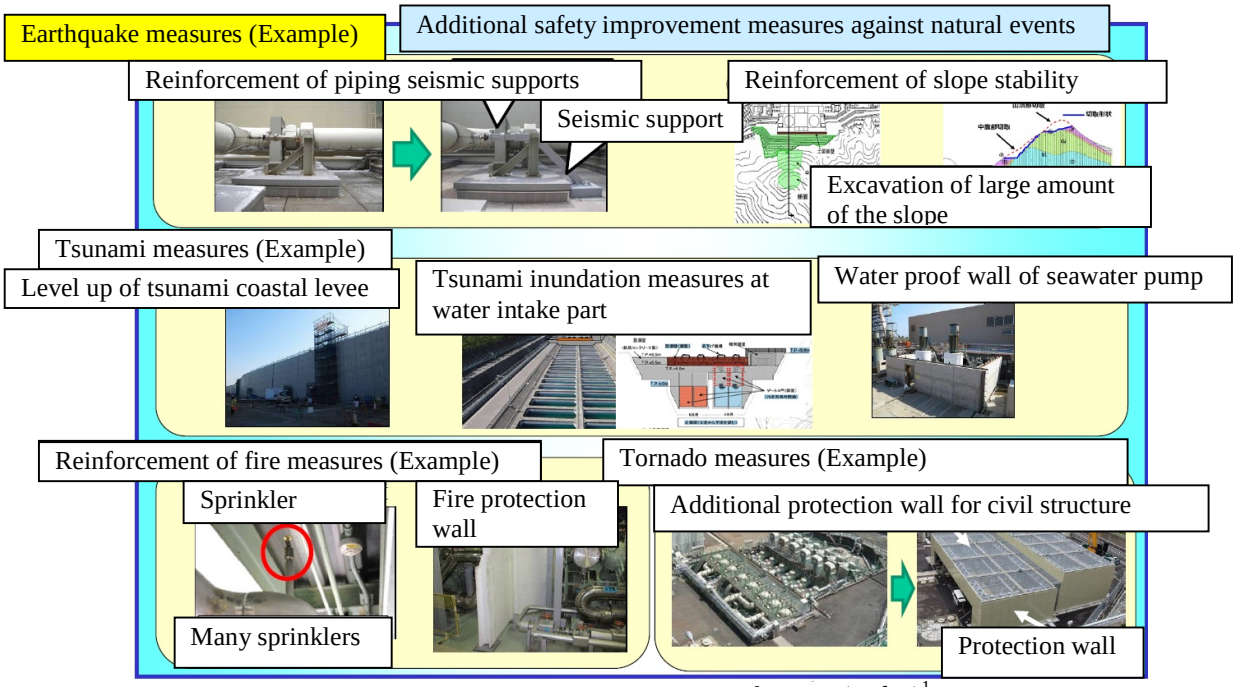


Figure-7: Measures against natural events (Ref. 4)[1]

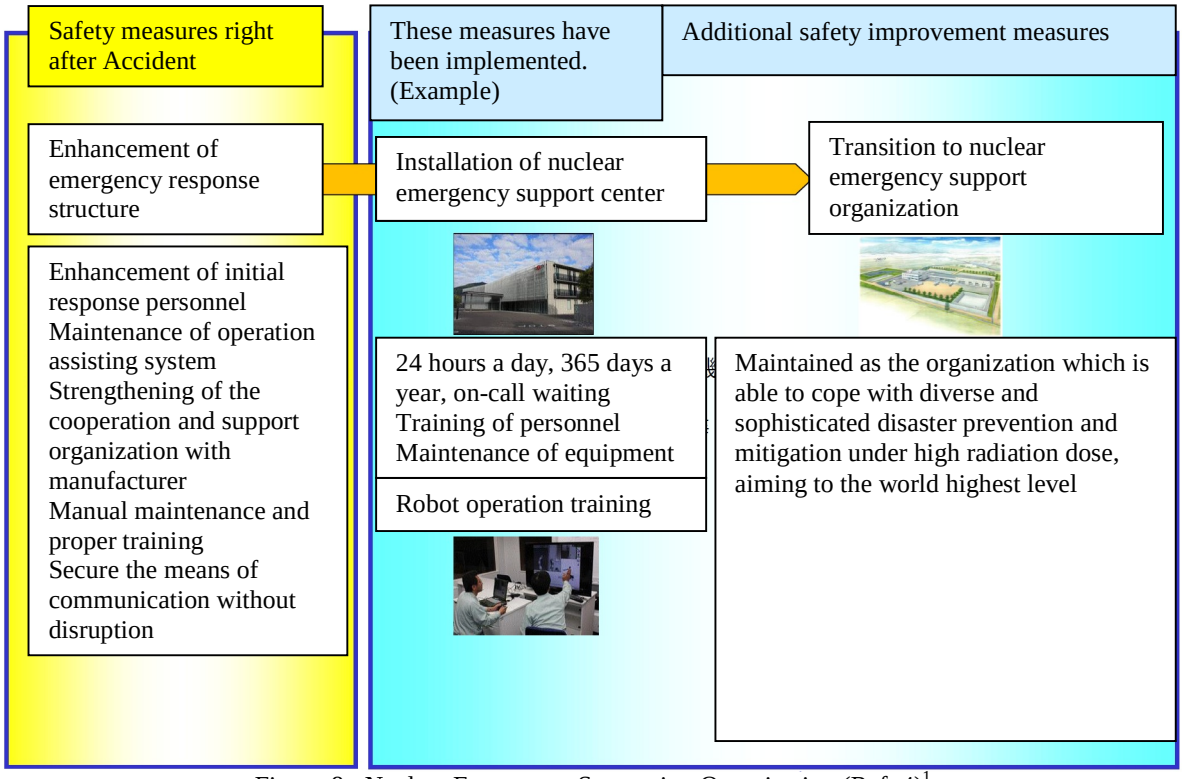


Figure-8: Nuclear Emergency Supporting Organization (Ref. 4)[1]

1 Although all the explanations described in Figure-7, -8 were originally written in Japanese, JANSI has translated them into English by its responsibility.

V. IDEA OF THE DEFENCE-IN-DEPTH CONCEPT AGAINST EXTERNAL EVENTS

Although Defence-in-Depth concept against external events does not seem to become clear in the new regulatory requirements, based on our extensive survey of the licensing documents that have been issued by NRA and reactor operators, we propose an idea of the Defence-in-Depth concept against external events in Japan as Figure-9.

As a premise of a discussion, the following Japan's special situations should be considered.

(1) Japan's new regulatory requirements shall be applied to new Nuclear Power Stations as well as existing Nuclear Power Stations without exception. This special requirement is called "back-fit rule" in Japan.
(2) Automatic scram system that is operated by the earthquake sensing device located on the base mat of Reactor Auxiliary Building of PWR and Reactor Building of BWR is installed at all Nuclear Power Stations in Japan. The system works by an earthquake smaller than the design basis earthquake.
(3) Dominant external natural events in Japan including earthquake and tsunami are much stronger than those in Western countries.
(4) Design basis accident measures in Japan include both Operating systems and Safety systems. In other words, Design basis accident measures are involved in Sequential Defence-in-Depth at three different levels (i.e. DiD-1, 2, 3). However, we have also found that some of the Design basis accident measures have an extended function into DiD-4 based on the survey of the licensing documents.
(5) Severe accident measures are involved in Sequential Defence-in-Depth at level 4 (i.e. DiD-4). However, we have also found that some of the severe accident measures have an extended function into DiD-3 based on the survey of the licensing documents.
(6) Based on the request by NRA, the reactor operators shall submit "Safety Improvement Evaluation Report" within six months after the second restart of their Nuclear Power Stations during the commercial operation period. The Report includes the latest stress test results, and the submission would be after about two years from the first restart at the earliest.

A discussion about Figure-3 is shown below.

(1) In Sequential Defence-in-Depth, the same hardware (systems, structures, components and etc.) and the same software (personnel, guidelines, training and etc.) are used against both internal events and external events.
(2) Smaller internal events like a failure of equipment or a mistake of staff will lead to multiple-failure of the given hardware or software.
(3) Larger internal events like "loss of power" or "system errors in design" will lead to common cause failure including the limited damage of the closely related hardware and software.
(4) External events like earthquake or tsunami will lead to common cause failure including the extreme damage of the widely related hardware and software.
(5) It is very important to prevent the extreme damage against external events by adopting the sufficient margin in "Defence-in-Depth against external events preventing common cause failure including extreme damage".

Table-1 shows the explanation of DiD-E1, -E2, -E3, -E4 at Figure-9.

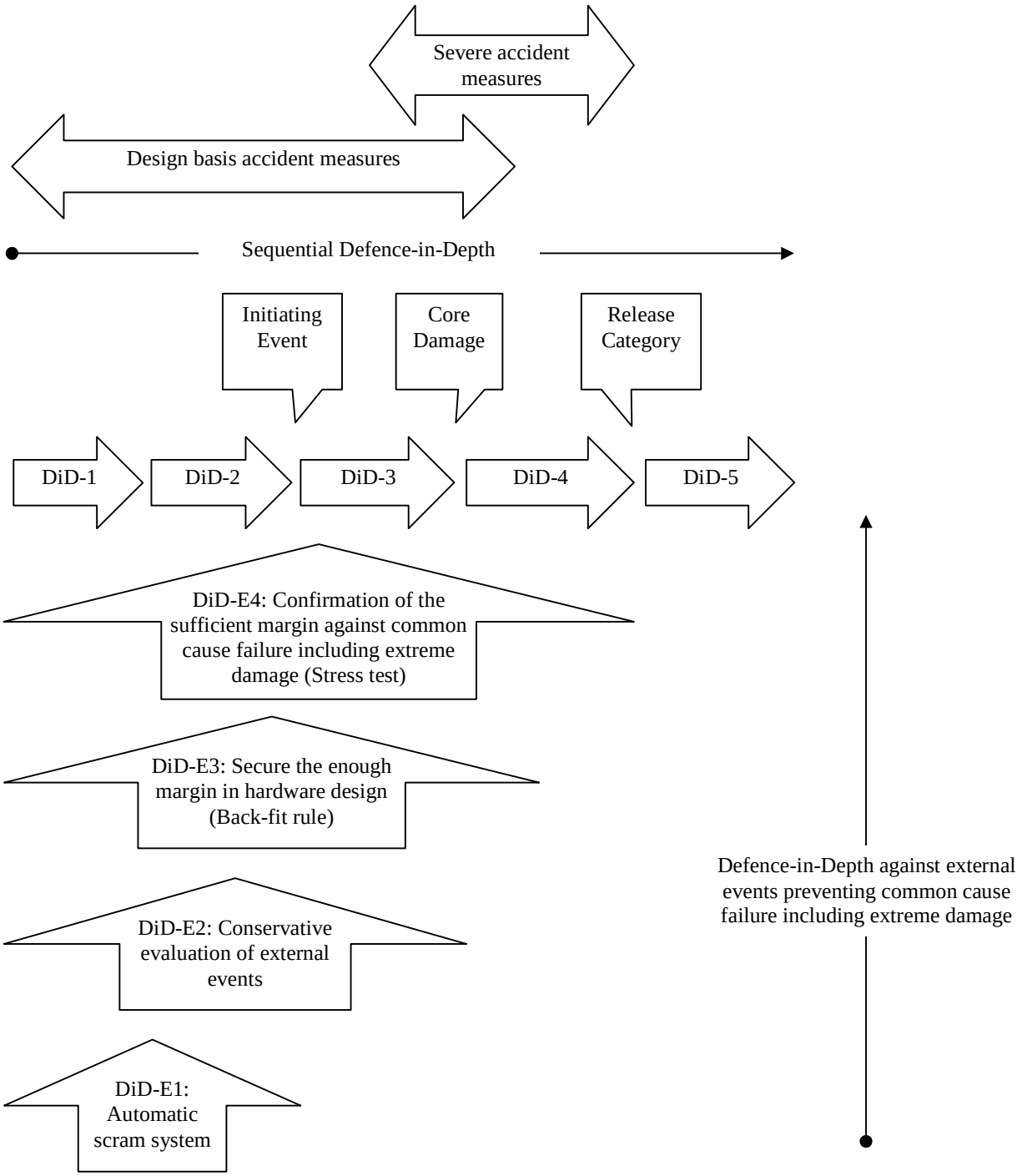


Figure-9: Idea of the Defence-in-Depth concept against external events in Japan

Table-1: Explanation of DiD-E1, -E2, -E3, -E4 at Figure-3

DiD Level	Name	Description	Relevant area in Sequential Defence-in-Depth	Example (The reference Nuclear Power Station was chosen from those which restarted successfully.)
DiD-E1	Automatic scram system	Automatic scram system that is operated by the earthquake sensing device located on the base mat of Reactor Auxiliary Building of PWR and Reactor Building of BWR is installed at all Nuclear Power Stations in Japan. The system works by an earthquake smaller than the design basis earthquake.	DiD-1 DiD-2	The system works by an earthquake level of 160 gal (horizontal) or 80 gal (vertical), in the reference Nuclear Power Station.
DiD-E2	Conservative evaluation of external events	Dominant external natural events in Japan including earthquake and tsunami are much stronger than those in Western countries.	DiD-1 DiD-2 DiD-3	The following design external events are adopted in the reference Nuclear Power Station. The same design external events are applied to “Design basis accident measures” as well as “Severe accident measures”. At present, the extra margin is not required to “Severe accident measures”. (1) Earthquake: Ss-1 (Horizontal: 540 gal, Vertical: 324 gal), Ss-2 (Horizontal: 620 gal, Vertical: 320 gal) (2) Tsunami: Defining position (Highest: +1.9 m, Lowest: -1.60 m), Water intake position (Highest: +4.94 m, Lowest: -5.43 m), Intake pit position (Highest: +5.02 m, Lowest: -3.40 m) (3) Snowstorm (Snowfall): Observed record near the Site (Maximum snowfall: 38 cm) (4) Volcano: Monitoring of volcanic activity against major calderas Design layer thickness of the drop pyroclastic (15 cm) (5) Windstorm (Typhoon): Observed record near the Site (Maximum wind speed: 62.7 m/s) (6) Freezing: Observed record near the Site (Lowest temperature: -6.7 degrees Celsius) (7) Tornado: Design maximum wind speed (92 m/s) (8) Forest fire: Large scale forest fire more than a firebreak (9) Biological event: Large scale invasion of marine organisms like jellyfish leading to the loss of seawater intake function (10) Lightning strike: Large scale lightning surge

DiD-E3	Secure the adequate margin in hardware design (Back-fit rule)	Japan's new regulatory requirements shall be applied to new Nuclear Power Stations as well as existing Nuclear Power Stations without exception. This special requirement is called "back-fit rule" in Japan.	DiD-1 DiD-2 DiD-3 DiD-4 (part)	"Back-fit rule" was strictly applied to the reference Nuclear Power Station. It means that the reference Nuclear Power Station conforms fully to the latest requirements. Thus, the reference Nuclear Power Station has an adequate margin which is included in the design criteria.
DiD-E4	Confirmation of the sufficient margin against common cause failure including extreme damage (Stress test)	Based on the request by NRA, the reactor operators shall submit "Safety Improvement Evaluation Report" within six months after the second restart of their Nuclear Power Stations during the commercial operation period. The Report includes the latest stress test results, and the submission would be after about two years from the first restart at the earliest.	DiD-1 DiD-2 DiD-3 DiD-4	The reference Nuclear Power Station is expected to submit the Report in a few years.

VI. CONCLUSIONS

Based on our extensive survey of the licensing documents that have been issued by NRA and reactor operators, we propose an idea of the Defence-in-Depth concept against external events in Japan.

ACKNOWLEDGMENTS

Our activities related to the evaluation of the Defence-in-Depth have been performed under the guidance of Dr. Misak (of Nuclear Research Institute – UJV Rez, Czech Republic). (Ref.5)

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