The Model of Resilience in Situation

Its contribution to the crisis management analysis and improvement

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INTRODUCTION

Context and goal of our research

- EDF initiated Post-Fukushima's actions to take into account beyond design basis events and Extreme Situations,
- As EDF R&D, we contribute to these actions by the estimation of EDF's Crisis Management Organization in terms of strengths and areas of progress of organizational resilience,
- We used our Model of Resilience in Situation (MRS) and we extended it to take into account the whole Crisis Management Organization,
- We will illustrate our model with the organization of seawater injection during the Fukushima Daichi accident.

Summary

What is resilience in real world?

Our approach: the MRS model

Extension to crisis management

1. What is resilience in real world?

A. ANTICIPATION
B. ADAPTATION

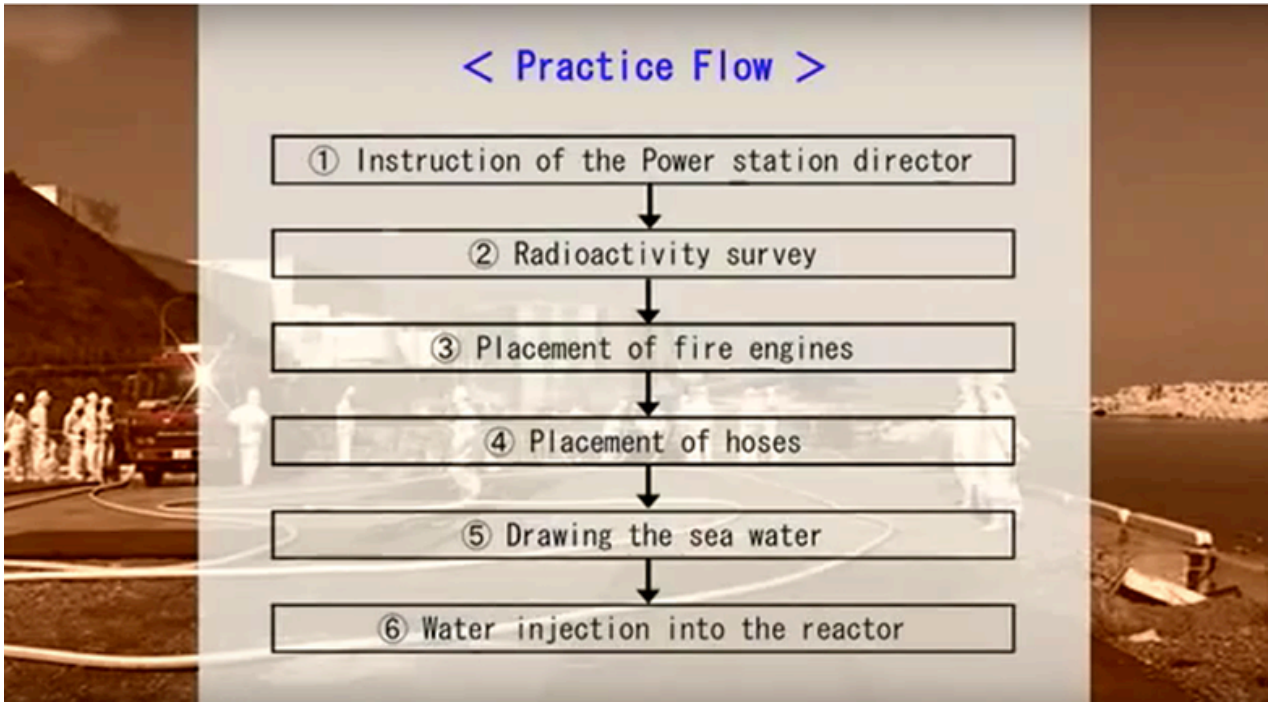
WHAT IS ANTICIPATION ?

TEPCO conducted a training drill at the Fukushima Daiichi site on October 12, 2011.

The following slides are drawn from public press handouts and a public video posted by TEPCO on its website

(http://photo.tepco.co.jp/en/date/2011/201110-e/111015-04e.html and https://www7.tepco.co.jp/wp-content/uploads/hd03-02-04-001-001-09-handouts_111012_02-e.pdf)

A procedure has been written to proceed to seawater injection



Beginning of the drill: a SBO and a tsunami are simulated then water injection in a reactor is lost

The manager asks to apply the procedure to inject seawater

The team on the field applies the procedure

Radioactivity Survey

Placement of fire engines

Placement of hoses

Placement of hoses

Setting up hose to the fire engine

Drawing the seawater

Drawing the seawater

Drawing the seawater

Pumping up seawater

End of the drill

Injecting water to temporary headers, designed to practice connection to feed water pipes

WHAT DOES THAT DRILL REPRESENT?

In order to prepare to management of the potential situations where seawater injection is required, the organization set up:

- Technical ressources (fire trucks, hoses …),
- A procedure,
- Staffing (TEPCO employees),
- Training by simulation (the drill),
- A crisis organization (TSC, headquarter, communications …).

Situations are anticipated: rules are defined before the occurrence of a situation. Lessons of March event are taken into account (organizational learning)

➔ **This is organizational ANTICIPATION**

WHAT HAPPENED IN THE MARCH EVENT WITH SEAWATER INJECTION ?

3 sources:

- TEPCO sources:
  - Press release May 26, 2011 "**The Time-line Regarding Seawater Injection to Unit 1 at Fukushima Daiichi Nuclear Power Station"** (http://www.tepco.co.jp/en/press/corp-com/release/11052603-e.html)
  - Report on initial responses to the accident at Tokyo Electric Power Co.'s Fukushima Daiichi Nuclear Power Plan - December 22, 2011

- Guarnieri, Franck; Travadel, Sébastien. Un récit de Fukushima. Le directeur parle (Hors collection) (French Edition) (p. 86). Presses Universitaires de France. Édition du Kindle.

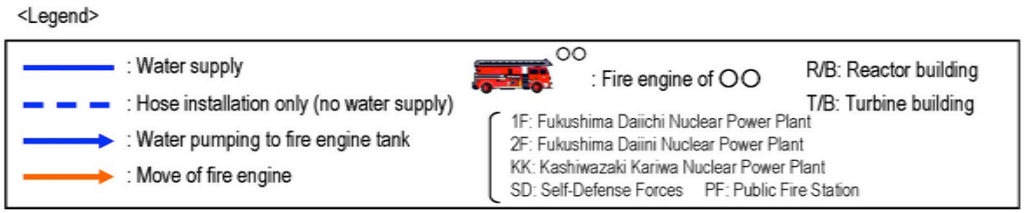
Seawater injection

Press release May 26, 2011 “The Time-line Regarding Seawater Injection to Unit 1 at Fukushima Daiichi Nuclear Power Station”

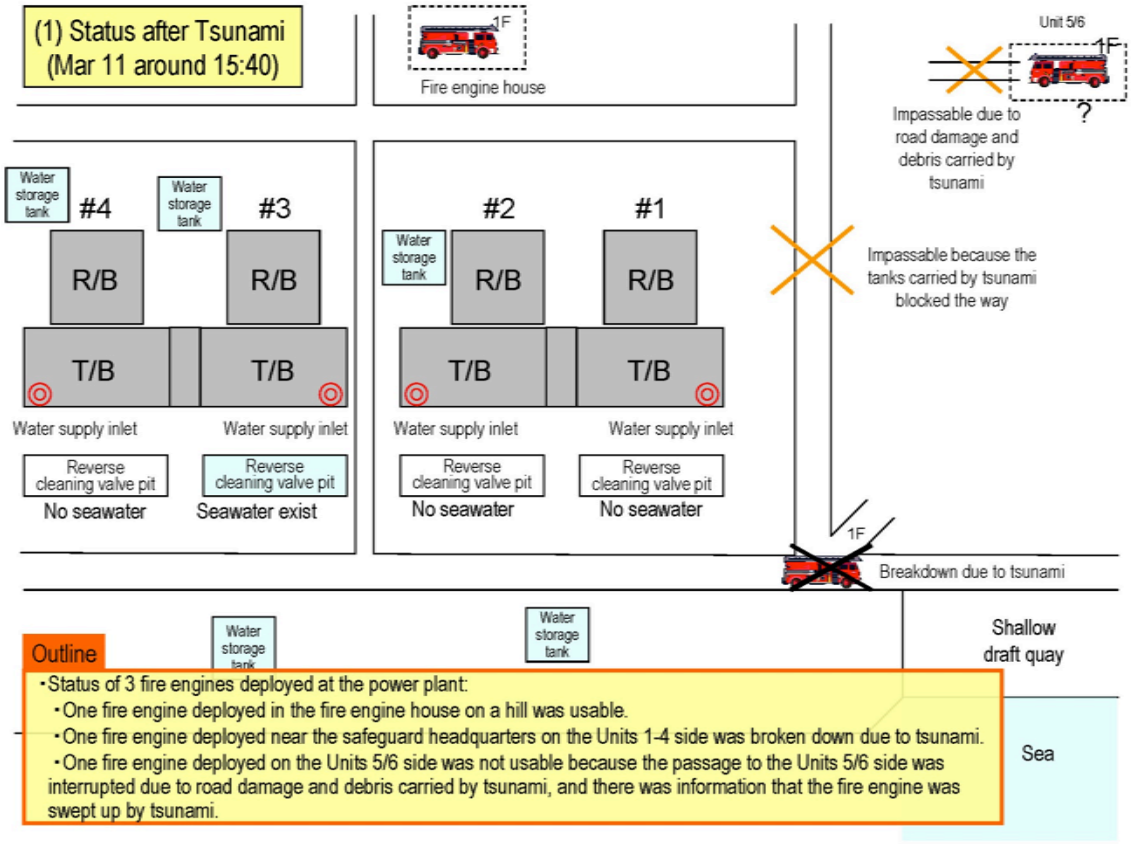
<Major time-line on March 12>

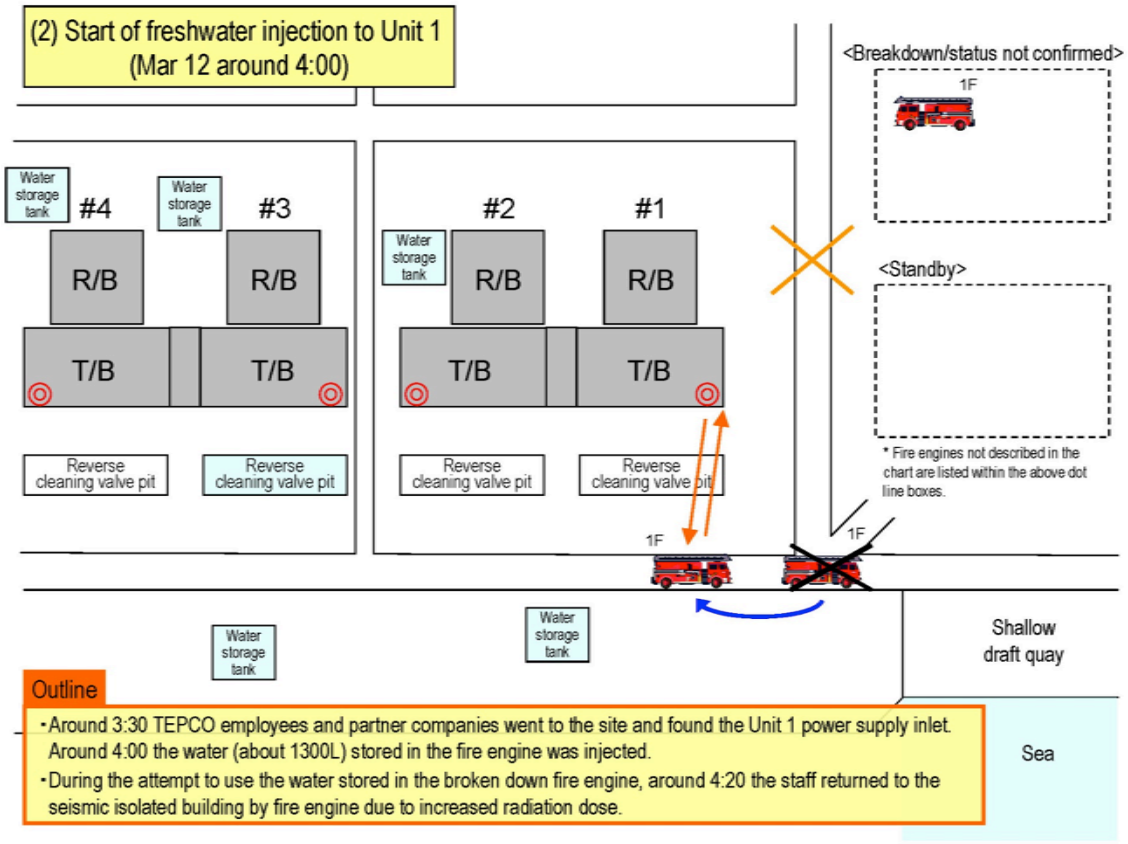
Approx.12:00pm	President confirmed and approved the preparation for seawater injection
Approx.2:50pm	President confirmed and approved the implementation of seawater injection
Approx.2:53pm	Injection of freshwater stopped (80,000l were injected at this point)
Approx.3:18pm	Reported to the Nuclear and Industrial Safety Agency (NISA) that we were scheduling to inject seawater once ready.
Approx.3:36pm	Hydrogen explosion
Approx.6:05pm	Received instruction from the government regarding seawater injection
Approx.7:04pm	Seawater injection was started
Approx.7:06pm	Reported to NISA about seawater injection
Approx.7:25pm	Based on the situational decision by our staff dispatched to the prime minister's office, the message stating "Prime minister's approval is not obtained regarding seawater injection here" was received at our headquarters and the power station. As a result of the discussion between headquarters and the power station, we decided to suspend the injection. However, seawater injection was continued per a decision by the site superintendent at the power station.(*)

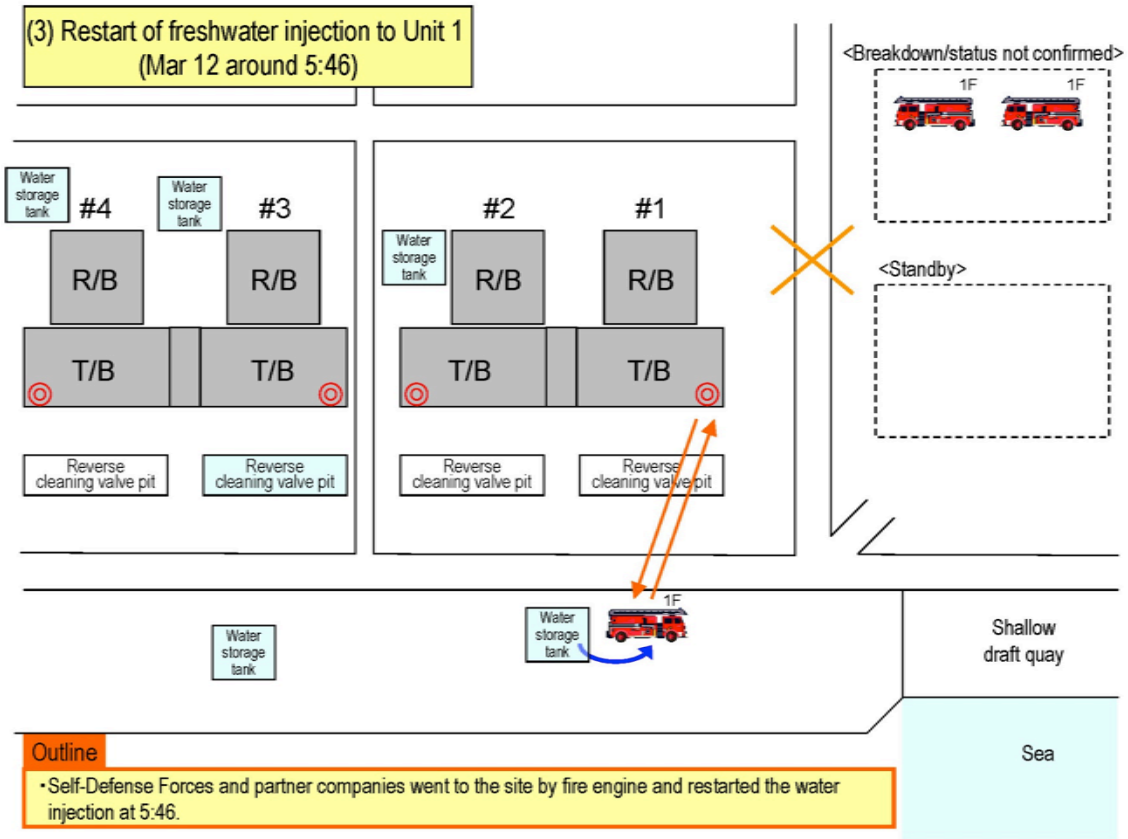
Outline of Water Injection to Reactors by Fire Engines

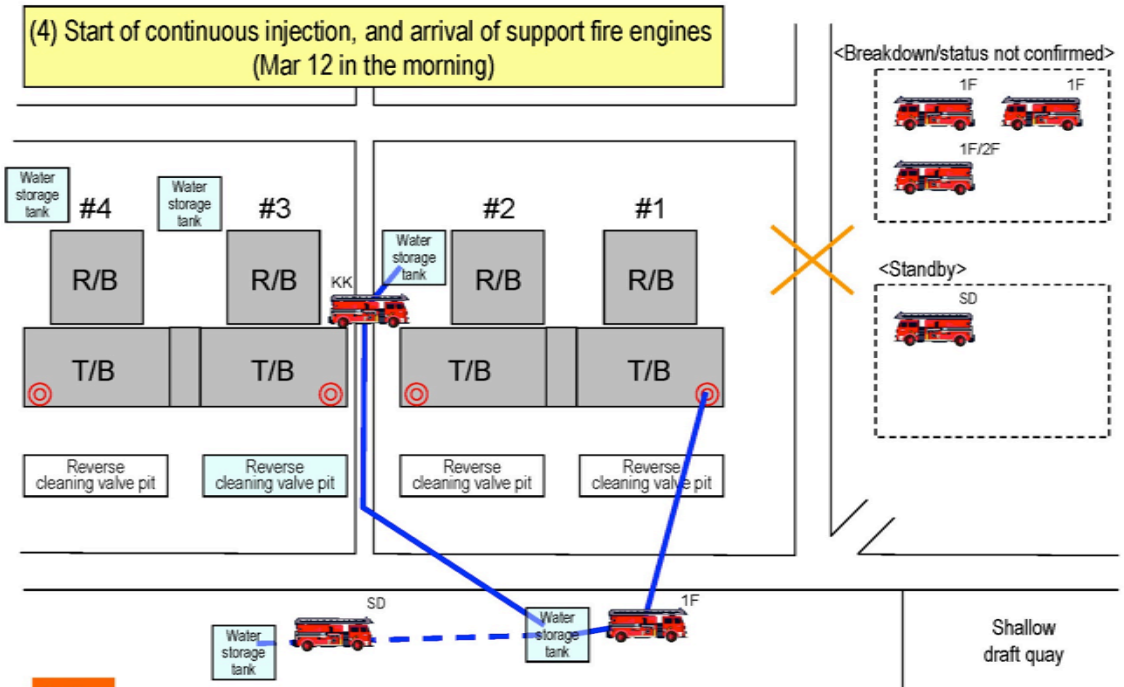


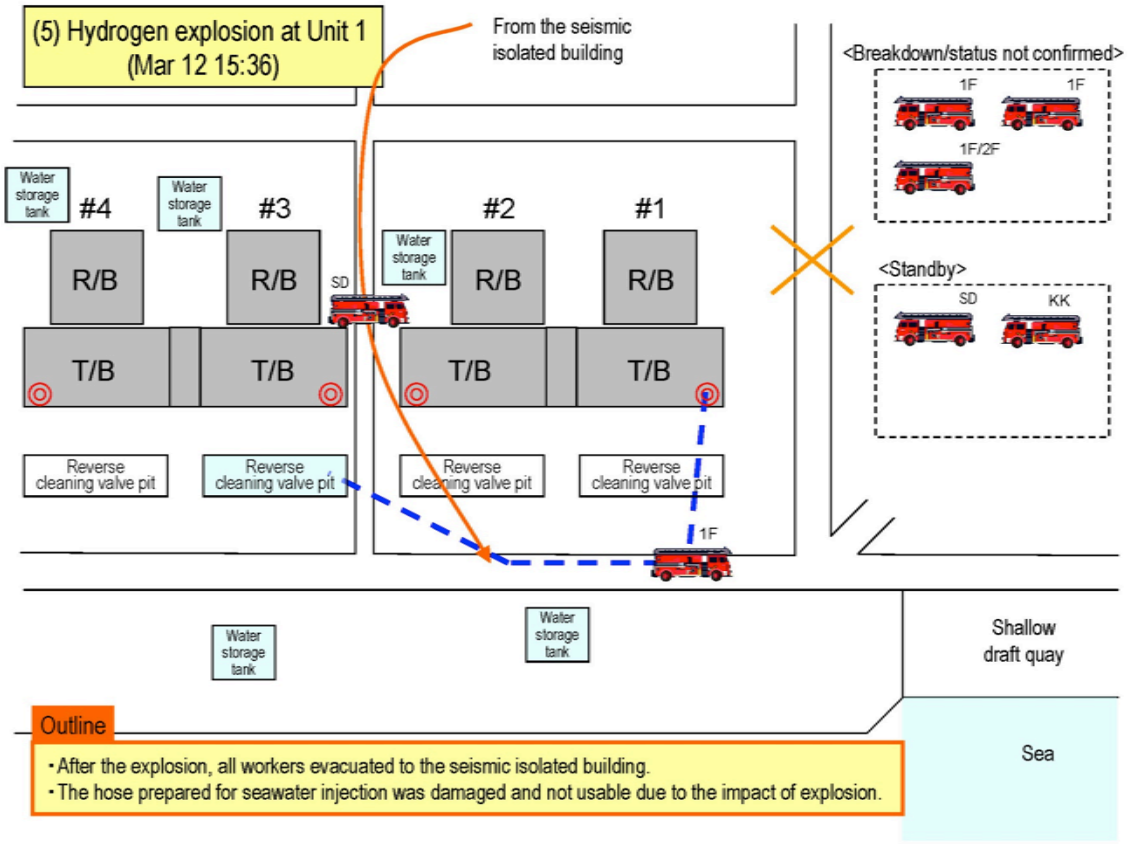
Report on initial responses to the accident at Tokyo Electric Power Co.'s Fukushima Daiichi Nuclear Power Plan - December 22, 2011

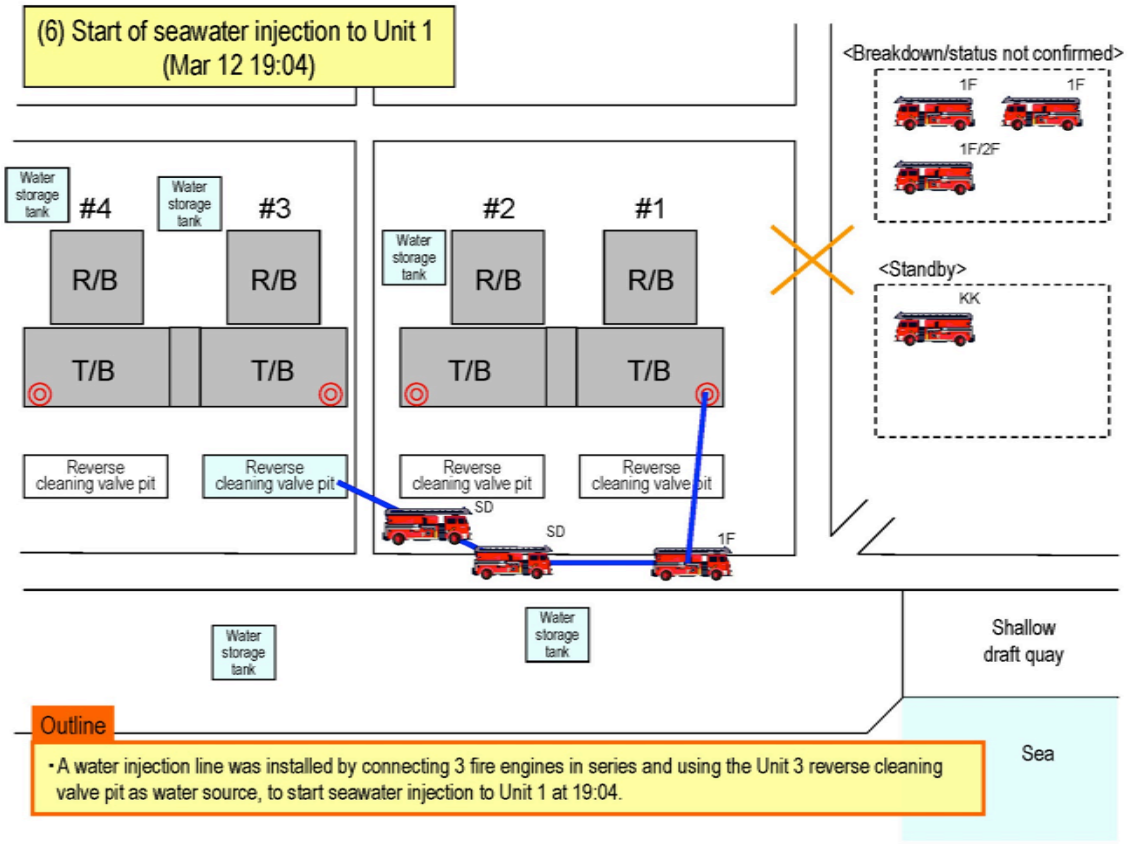

(1) Status after Tsunami
(Mar 11 around 15:40)
1F
Fire engine house
Unit 5/6
1F
?
Impassable due to road damage and debris carried by tsunami
Water storage tank
#4
Water storage tank
#3
#2
#1
Water storage tank
R/B
R/B
R/B
R/B
T/B
T/B
T/B
T/B
Impassable because the tanks carried by tsunami blocked the way
Water supply inlet
Water supply inlet
Water supply inlet
Water supply inlet
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
No seawater
Seawater exist
No seawater
No seawater
1F
Breakdown due to tsunami
Water storage tank
Water storage tank
Shallow draft quay
Sea
Outline
・Status of 3 fire engines deployed at the power plant:
・One fire engine deployed in the fire engine house on a hill was usable.
・One fire engine deployed near the safeguard headquarters on the Units 1-4 side was broken down due to tsunami.
・One fire engine deployed on the Units 5/6 side was not usable because the passage to the Units 5/6 side was interrupted due to road damage and debris carried by tsunami, and there was information that the fire engine was swept up by tsunami.

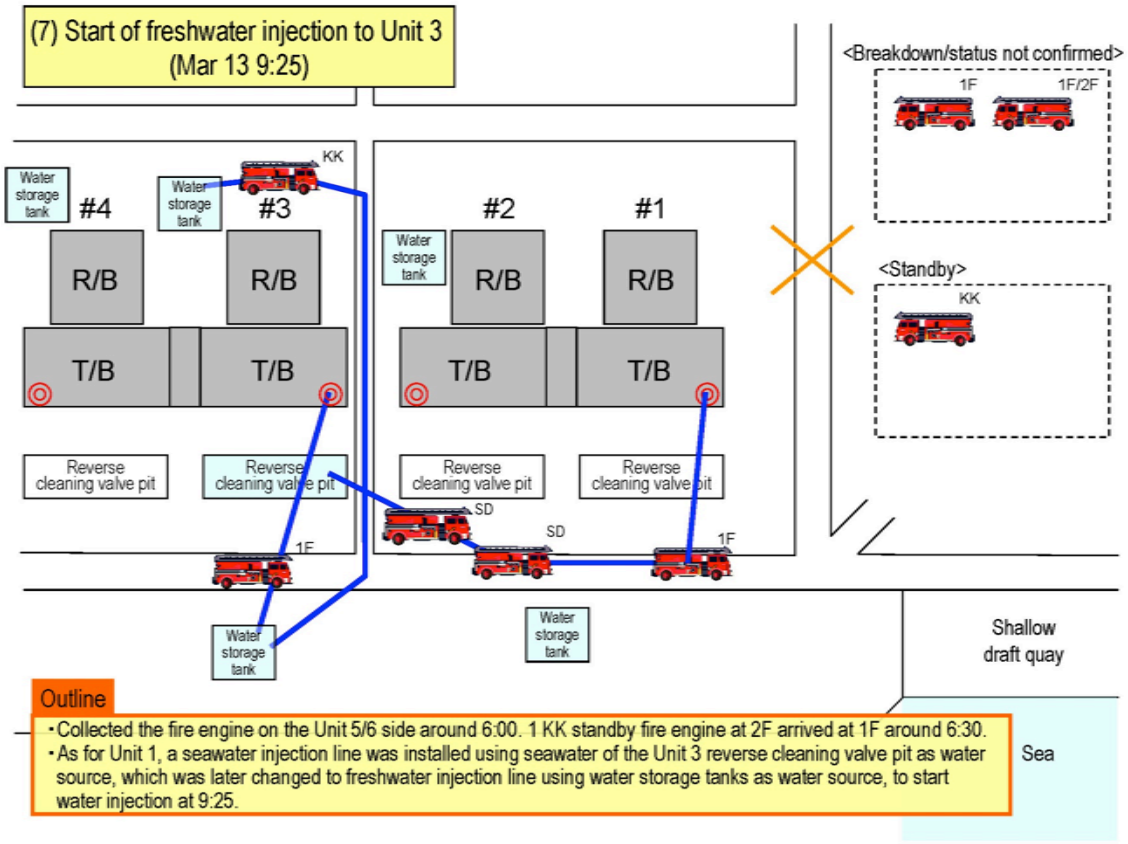

(2) Start of freshwater injection to Unit 1
(Mar 12 around 4:00)
<Breakdown/status not confirmed>
1F
<Standby>
* Fire engines not described in the chart are listed within the above dot line boxes.
Water storage tank
#4
#3
#2
#1
R/B
T/B
Reverse cleaning valve pit
1F
Shallow draft quay
Sea
Outline
・Around 3:30 TEPCO employees and partner companies went to the site and found the Unit 1 power supply inlet. Around 4:00 the water (about 1300L) stored in the fire engine was injected.
・During the attempt to use the water stored in the broken down fire engine, around 4:20 the staff returned to the seismic isolated building by fire engine due to increased radiation dose.


(3) Restart of freshwater injection to Unit 1
(Mar 12 around 5:46)
<Breakdown/status not confirmed>
1F
1F
<Standby>
Water storage tank
#4
Water storage tank
#3
#2
#1
Water storage tank
R/B
R/B
R/B
R/B
T/B
T/B
T/B
T/B
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
1F
Water storage tank
Water storage tank
Shallow draft quay
Sea
Outline
・Self-Defense Forces and partner companies went to the site by fire engine and restarted the water injection at 5:46.


(4) Start of continuous injection, and arrival of support fire engines (Mar 12 in the morning)
<Breakdown/status not confirmed>
1F
1F
1F/2F
<Standby>
SD
Water storage tank
#4
Water storage tank
#3
#2
#1
Water storage tank
KK
R/B
R/B
R/B
R/B
T/B
T/B
T/B
T/B
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
SD
1F
Water storage tank
Water storage tank
Shallow draft quay
Outline
・Continuous water injection line from the water storage tank to water supply inlet was installed to inject water.
・KK arrived at the site around 10:30, and the fire engine of Self-Defense Forces arrived before noon. Water was supplied from water storage tanks around the site to the water storage tanks to the Unit 1 side.
・In addition, 1 chemical fire engine shared by 1F and 2F was moved from 2F. (The fire engine was not used actually because of its old model.)


(5) Hydrogen explosion at Unit 1
(Mar 12 15:36)
From the seismic isolated building
<Breakdown/status not confirmed>
1F
1F
1F/2F
<Standby>
SD
KK
Water storage tank
#4
#3
#2
#1
R/B
T/B
SD
Reverse cleaning valve pit
1F
Shallow draft quay
Sea
Outline
・After the explosion, all workers evacuated to the seismic isolated building.
・The hose prepared for seawater injection was damaged and not usable due to the impact of explosion.


(6) Start of seawater injection to Unit 1
(Mar 12 19:04)
<Breakdown/status not confirmed>
1F
1F
1F/2F
<Standby>
KK
Water storage tank
#4
Water storage tank
#3
#2
#1
Water storage tank
R/B
R/B
R/B
R/B
T/B
T/B
T/B
T/B
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
Reverse cleaning valve pit
SD
SD
1F
Water storage tank
Water storage tank
Shallow draft quay
Sea
Outline
・A water injection line was installed by connecting 3 fire engines in series and using the Unit 3 reverse cleaning valve pit as water source, to start seawater injection to Unit 1 at 19:04.

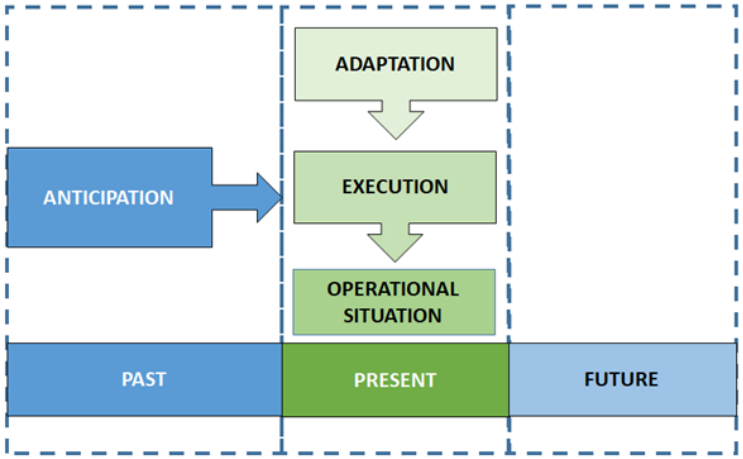

(7) Start of freshwater injection to Unit 3
(Mar 13 9:25)
<Breakdown/status not confirmed>
1F
1F/2F
<Standby>
KK
Water storage tank
#4
#3
#2
#1
R/B
T/B
Reverse cleaning valve pit
SD
1F
Shallow draft quay
Sea
Outline
・Collected the fire engine on the Unit 5/6 side around 6:00. 1 KK standby fire engine at 2F arrived at 1F around 6:30.
・As for Unit 1, a seawater injection line was installed using seawater of the Unit 3 reverse cleaning valve pit as water source, which was later changed to freshwater injection line using water storage tanks as water source, to start water injection at 9:25.

WHAT DOES THAT REPORT SHOW?

- A real situation has always unanticipated features and with beyond design basis events and Extreme Situations organizations have to face maximal and dangerous unexpected conditions:
  - Unanticipated accident (SBO with loss of internal electrical supplies, multiple reactors damaged simultaneously …),
  - Degraded working environment (flooding due to the tsunami, aftershocks, radiations, inaccessible facilities …).
- Initially, resources are missing, and thereafter managing new resources and supports that arrive is difficult:
  - Lack of knowledge, procedures, resources & means to inject water, …
  - Some unusable resources has to be dropped down (older model fire truck …),
  - Emergency support teams help but may prevent the local initiatives (disagreement on seawater injection).
- Organization must give up their most demanding goals, and initiatives are needed to invent new objectives, new procedures and new roles:
  - To give up injecting only fresh water, …
  - How to inject with enough pressure with fire trucks pumps, …
  - All workers on the field contribute in turn to refuel the fire trucks while they are injecting seawater.

➔ **organizational ADAPTATION IS NEEDED**

Organizations must anticipate before emergency situations AND adapt during each situation



organizational ability to combine anticipation and adaptation is **resilience**

2. Our approach: the MRS model

We build the Model of Resilience in Situation in order to understand organizational resilience from:

- Empirical experience (simulations, industrial accidents)
- Sociology (J.D. Reynaud Theory of Social Regulation),
- Human Reliability approach (MERMOS)
- Cognitive Ergonomics

Yoshida interview

Guarnieri, Franck; Travadel, Sébastien. Un récit de Fukushima. Le directeur parle (Hors collection) (French Edition) (p. 86). Presses Universitaires de France. Édition du Kindle.

HOW TO INJECT WATER: COLLABORATION

… It was obvious that we would arrive quickly enough to exhaust the fresh water. … So it was obvious to me that we would be able to inject seawater; there was no other way… **I had ordered the Fire group to study how to inject seawater**. Because if it is necessary to go to pump the water at sea level, it must be raised by 10 meters. With a conventional fire pump, it does not go up. Here is the sea. It is 4 meters above sea level and here it is 10 meters. There is the turbine building, and that's where you have to bring the water. Which means you have to go up 10 meters. With ordinary suction, you can not do it. …

… In the meantime, we knew that the tsunami water, seawater, remained in the basin adjacent to the turbine of reactor 3. So I gave the order to use this water. It was really difficult. **While taking advantage of this water, it was necessary to think of a means of supplying this basin with the sea water.** Then, by chance, several fire trucks arrived. So we put them on a network here on this platform. We went up the water using two as a booster, then another here as a relay. But that was later. Initially, for reactor 1, the water left by the tsunami was used. A very down-to-earth solution. But we could not do better .....

… I had not kept (the seat) informed of these preparations or the details .... **One spreads the plans and one says oneself: there, it will not pass**. **One wonders how many pumps one has, how many fire trucks**. They are two**. We discuss lots of things, possibilities around plans.** But the seat does not have to know all that. In any case, even after a million years, they are absolutely not able to pull out information such as: "There is seawater in a turbine pool", so we have to to look for solutions on the ground.

… **We changed the method several times and I do not really remember how much I exchanged with the men on the ground.** I still have not managed to put things back in order, but in principle, we started by injecting the water that was available, and then we were restocking. And at the same time we did that, **we decided to use the water from the fire tank.** But we had pressure problems, then, by chance, other trucks arrived from outside and, by passing a truck to three, we managed to increase the pressure of exit**. All this was done on the ground improvising. I do not remember when such a specific thing happened**. It should be asked to those who were on the ground. For my part**, I asked that we inject the water in the most efficient and continuous way possible.**

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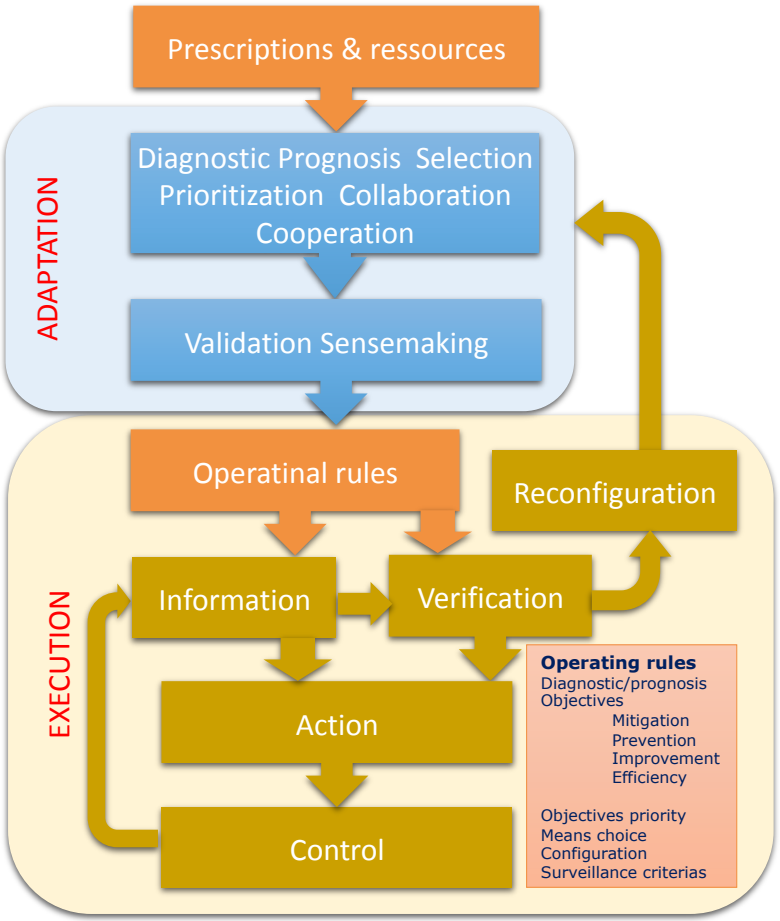


Seawater Injection as an example of adaptation process

Diagnostic: no more freshwater available near unit 1, diesel fire pump unavailable, not enough pressure with only one fire truck pump,

Prognostic: freshwater has been asked to support teams but no supply in short term, if no injection core will melt

Selection (*of resource***)** : use seawater instead of freshwater, three fire trucks, injection by unit 1 fire circuit inlet, use of seawater from a pit filled by the tsunami

Prioritization : use all the available fire trucks on unit 1 at the expense of unit 2 or unit 3. At first exposure to radiation of older workers

Collaboration: dialog between Main control room and ERC, use of rich experiences from the plant operation, main line of strategy by Yoshida, more details rules by the field …

Cooperation : implementation of the alternate injection lines by ERC teams, Fire Brigade and Main Control Room

Validation: Yoshida decides to perform raw seawater injection in the core

Sensemaking: the national supports disagreed with this strategy but Yoshida pretended to stop seawater injection while in reality pursuing it.

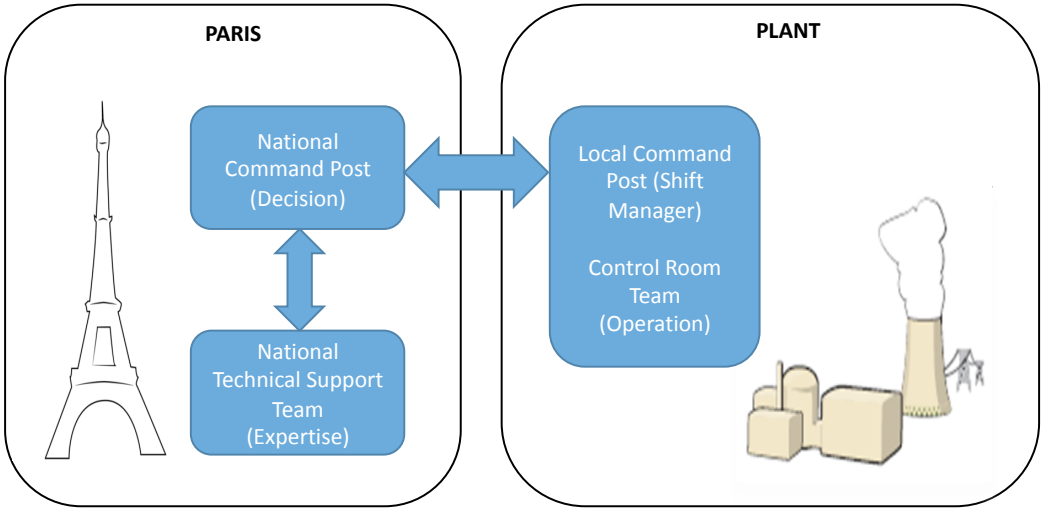
Operational rules:

- Inject seawater with hoses from a pit filled by the tsunami to unit 1 inlet, with 3 fire trucks in series
- Refuel fire trucks by older workers

The MRS

- A model of organizational resilience
- Focused on the teamwork in situation
- To understand how anticipation and adaptation are combined in situation by a dynamic succession of phases of
    - Stabilisation, during which the teamwork is driven by operational rules
    - And rupture, where the team selects, adapts or defines operational rules
- Composed by processes (anticipation, adaptation …) and functions
- To understand how each organizational feature influences functions and then processes

3. MRS extension to study Crisis Management Organization



Resilient organization as a network of resilient teams

Simulations of Extreme situations

Examples of insights:

- Completing collaboration and cooperation in the model with coordination
- Dependency between synchronization of teams and sensemaking

…

Thank You for your attention