NRA , Japan
Nuclear Regulation Authority

Keynote Presentation

Summary on Fukushima Related Activities in Japan

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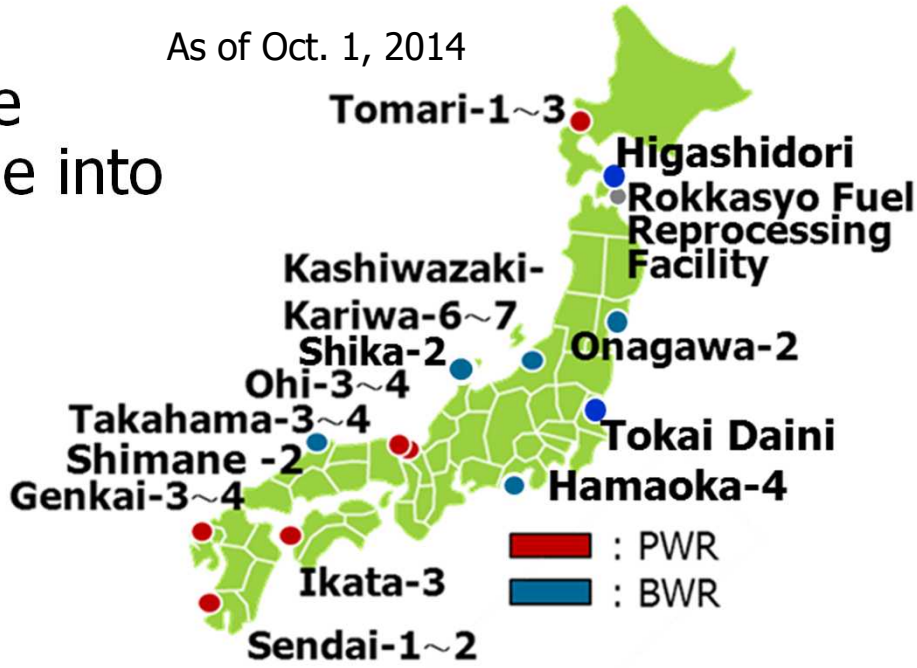
International Conference on Challenges Faced by TSOs
in Enhancing Nuclear Safety and Security:
Strengthening Cooperation and Improving Capabilities,

27-31 October 2014, Beijing, China

Contents

Current Status of Safety Regulation

- NRA was established in **Sep. 2012** and developed the new regulatory requirements for NPPs which came into force in **July 2013**.
  - **All the 48 units** have been shut down **since Sep. 2013**.
  - So far, a total of **20 units**, 12 PWRs and 8 BWRs, have applied for **conformance review** for restart.
  - In **Sep. 2014**, NRA first approved the applications from **Sendai Units 1 and 2**.
- The new requirements for fuel cycle facilities and research reactors came into force in **Dec. 2013**.
- The former **JNES was merged with NRA** on **Mar. 1, 2014**.
- NRA invited the **IAEA IRRS mission** to be taken place in **late 2015**.



Some Lessons Learned Identified in Diet's Report (Reported to Diet in July 2012)

NAIIC : The National Diet's Fukushima Nuclear Accident Independent Investigation Commission

Message from Chairman

- … this was a disaster "**Made in Japan**." Its fundamental causes are to be found in the … **Japanese culture**: our **reflexive obedience**; our **reluctance to question authority**; … and our **insularity**.

Organizational issues …

- … actual relationship **lacked independence** and **transparency**, … In fact, it was a typical example of "**regulatory capture**," …

Lack of expertise

- … the two incorporated technical agencies advising NISA, namely, **JNES and JAEA**, have been **too rigidly tied to NISA** ….

Conclusions

- … **The lack of expertise** resulted in "**regulatory capture**,"… They **avoided their direct responsibilities** by **letting operators apply regulations on a voluntary basis.**

NRA: Nuclear Regulation Authority
Established in Sept. 2012

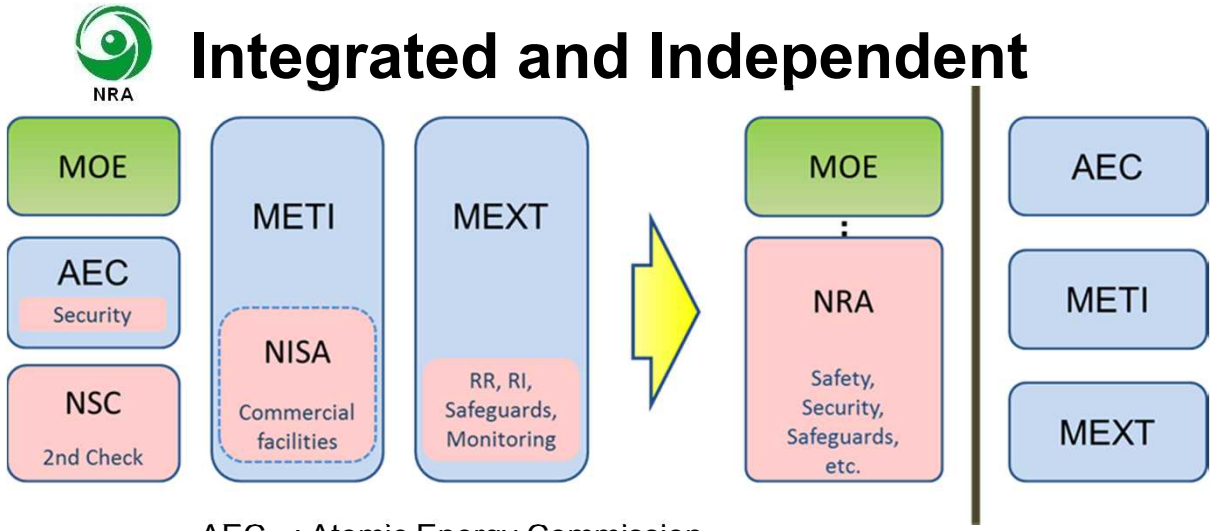
Independence

Nuclear regulation and nuclear promotion were clearly separated, and the NRA was established as **an independent commission body** defined by law* affiliated with MOE (Minister of Environment).

* a council-system organization based on Article 3 of the National Government Organization Act, ensuring its independence without any control or supervision by other organizations.

Integrated

Nuclear regulation functions regarding safety, security, safeguards, radiation monitoring and radioisotopes were integrated into the NRA.



AEC : Atomic Energy Commission
METI : Ministry of Economy, Trade and Industry
MEXT : Ministry of Education, Culture, Sports, Science and Technology
MOE : Ministry of the Environment
NISA : Nuclear and Industrial Safety Agency (abolished)
NSC : Nuclear Safety Commission (abolished)

- T. Fuketa, NRA, presented at U.S.NRC RIC2013, March 13, 2013.
- http://www.nsr.go.jp/english/e_nra/leaflet/data/nsr_leaflet_English.pdf

"Technical Independence"

Report from OECD/NEA/CNRA, "**The Characteristics of an Effective Nuclear Regulator**", NEA/CNRA/R(2014)3

Utmost important elements for being **effectively independent** from undue influence in decision making:

- **Political independence**
  - Authorized and being able to make independent regulatory judgments and regulatory decisions within their field of competence for routine work and in crisis situations. …
- **Financial independence**
  - Provided with sufficient financial resources, reliable funding and staffing for the proper and timely discharge of its assigned responsibilities. …
- **"Technical independence"**
  - Possess **technical and scientific competence** and the capacity to make independent decisions.
  - Has access to independent **scientific and technical support**.

Merger of JNES with NRA

- The former **JNES** was merged with **NRA** on March 1, 2014 to enhance the **technical competence / expertise of NRA**.
- **Regulatory Standard and Research Department** (**S/NRA/R**) consisting of mostly research engineers from JNES was created as "**internal TSO**" for:
  - Developing **technical standards and guides**, and
  - Conducting **safety research**.
- Cooperation with **NSRC** (Nuclear Safety Research Center) in **JAEA** and **NIRS** (National Institute for Radiological Sciences), "**external TSOs**" for NRA, has been strengthened.
- **NRA** succeeds basically all the **international cooperative activities** through the IAEA, OECD/NEA, ETSON, etc. or bilateral agreements which the former JNES had participated in.

Basic Policies Set out in Major Acts Amended in June 2012

Basic Act for Atomic Energy

IAEA SF-1

- Safety objective was stipulated in Article 2:

  To protect people's lives, health and property, and the environment, and to contribute to security …
  taking into account established **international standards**

IAEA Safety Standards, etc.

Nuclear Regulation Act

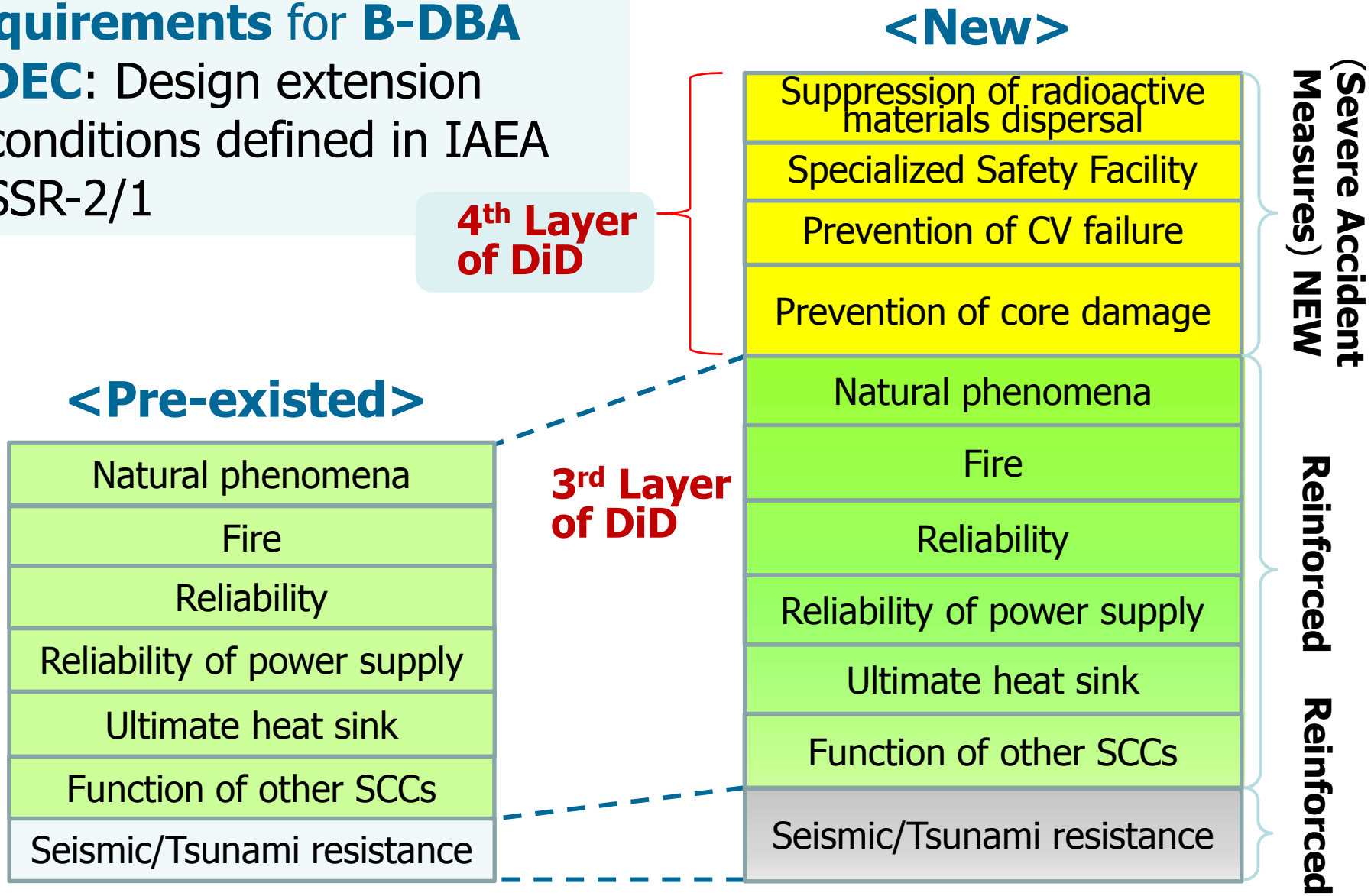
- Mandatory **severe accidents measures**
- **Back-fitting** to existing plants
- **Licensee's primary responsibility for safety**
- **Limit of operation of 40 years** for NPPs with possible extension up to 20 years just once
- Special regulation applied to **disaster-experienced plant** (Fukushima Daiichi), etc.

http://www.nsr.go.jp/english/library/data/related_act_140301-02.pdf

New Regulatory Requirements: Structure

Requirements for B-DBA

- **DEC**: Design extension conditions defined in IAEA SSR-2/1

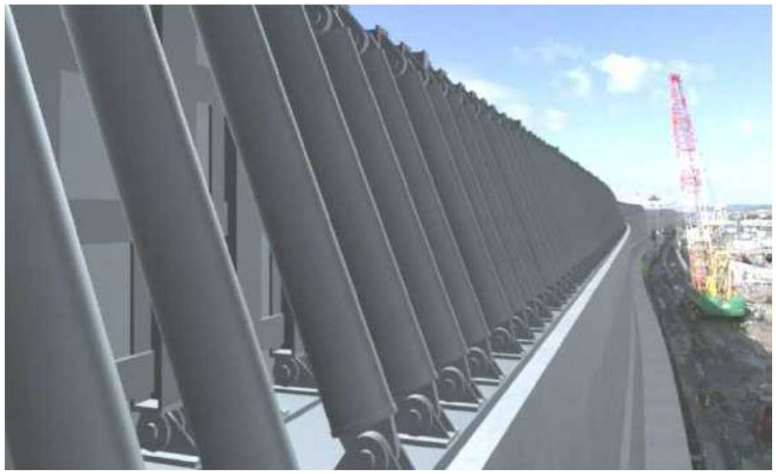


New Regulatory Requirements:
Enhanced Measures against Tsunami

More Stringent Standards on Tsunami	It is required to define "design basis tsunami" that **exceeds the largest in the historical records** and to take **protective measures** such as **breakwater wall** based on it.
Enlarged Application of Higher Seismic Resistance	SSCs for tsunami protective measures are **classified as Class S** equivalent to RPV etc. of **seismic design importance classification**.

Example of protective measures against tsunami (multiple measures)

- **Breakwater wall** for prevention of inundation to the site

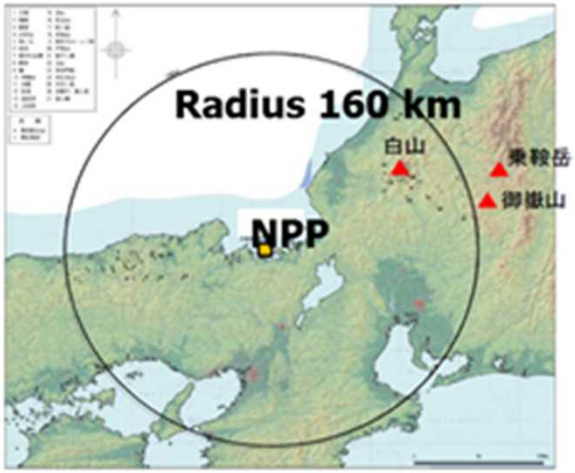


- **Tsunami gate** for prevention of water penetration into the building

http://www.nsr.go.jp/english/data/20130313presen.pdf

New Regulatory Requirements: Measures against Extreme Natural Phenomena

- In order to prevent **common cause failure**, it is required to take measures against **volcano eruption**, **tornadoes** and **forest fire**, postulating severe conditions.
- Example: **Review Guide for Impacts of Phenomena**
  - Assess the possibility that "**severe volcanic phenomena which design cannot cope with**" reach to the site **during the plant life**.
  - Even if the possibility is small, it is required to conduct **monitoring** and **develop policy on reactor shutdown, fuel unloading**, etc. when **volcanic unrest** is identified.
  - IAEA **SSG-21** "**Volcanic Hazards in Site Evaluation**" gave us valuable inputs.

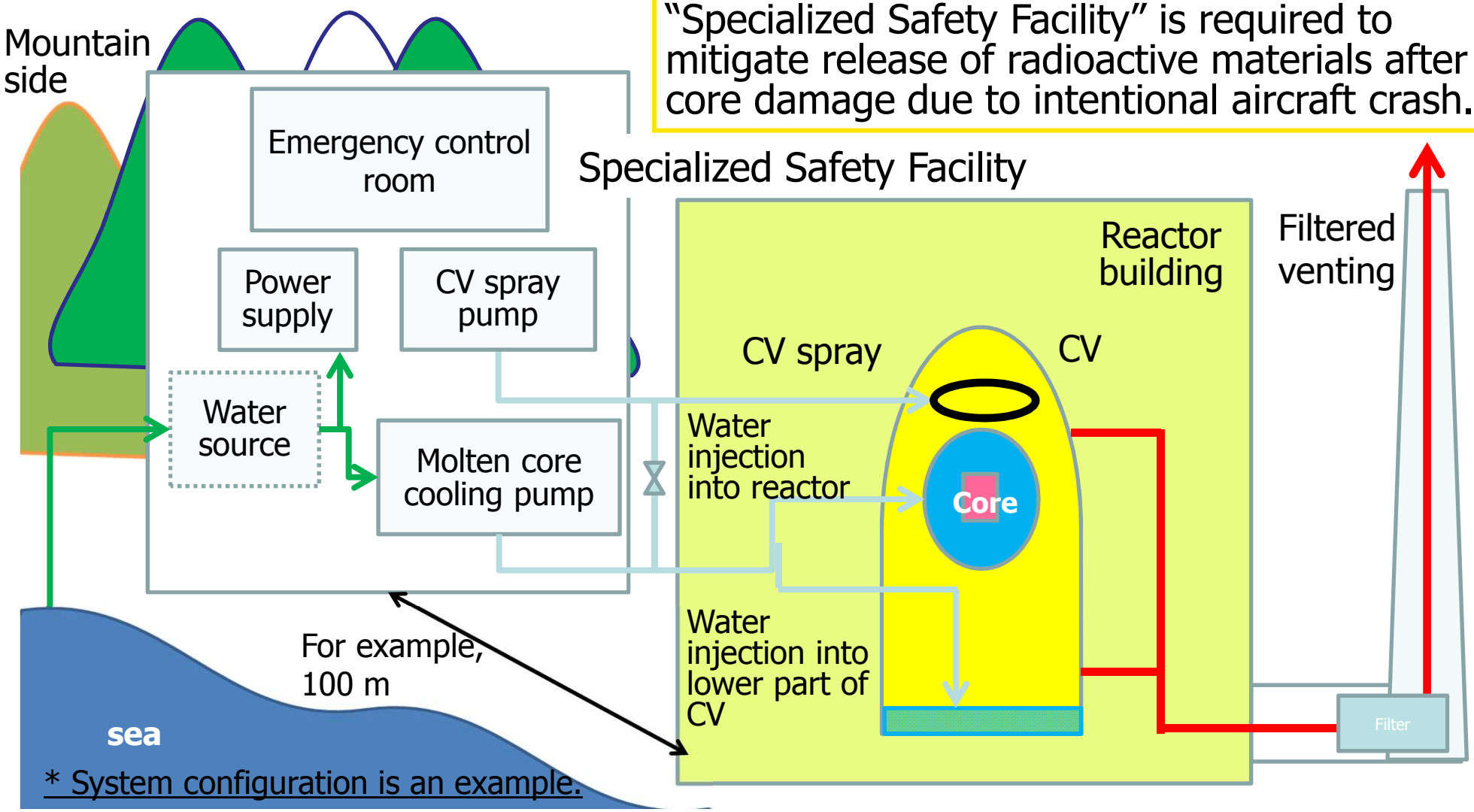


Pyroclastic flows
at Mayon Volcano Philippines, 1984

http://en.wikipedia.org/wiki/File:Pyroclastic_flows_at_Mayon_Volcano.jpg

New Regulatory Requirements:
Measures against Intentional Aircraft Crash, etc.

"Specialized Safety Facility" is required to mitigate release of radioactive materials after core damage due to intentional aircraft crash.



For BWR, one filtered venting for prevention of containment failure and another filtered venting of Specialized Safety Facility are acceptable solution.

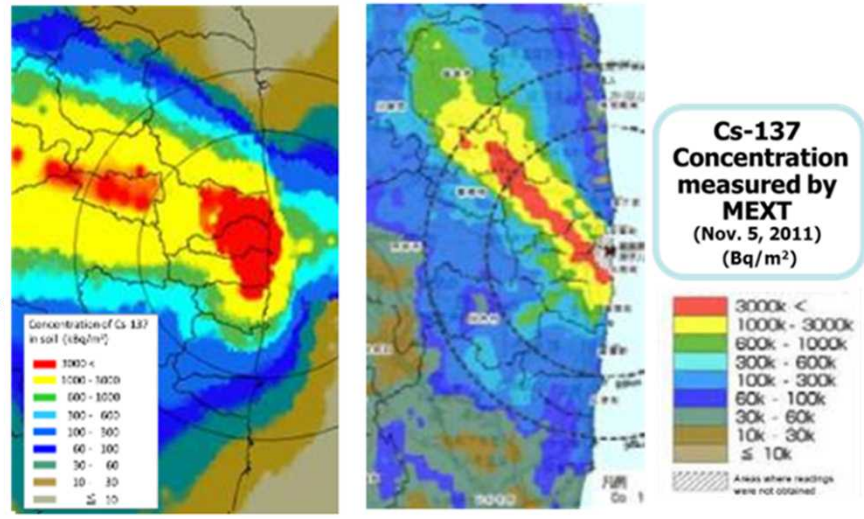
Focus in Safety Research

- Special emphasis on **external / internal hazards** leading to large scale **common cause failure**:
  - **Extreme natural phenomena**:
    - **Hazard curves** of earthquake/tsunami, **fragilities** of SSCs
    - Monitoring of **volcanic unrests**, …
  - **PRA** methods and models: External/internal **fire** and **floods**, multi-hazards, **multi-units**, application of **level 3 PRA**
- Research on **Severe Accidents** (SAs):
  - **Code development** for SA progression / source terms, …
  - Experiments on **scrubbing**, **seawater injection**, **SFP LOCA**
- Research on **Fukushima Daiichi**:
  - Management of wastes/contaminated water, **risk assessment**
  - **Criticality of fuel debris**, etc.
- Other areas:
  - **Decommissioning**/**waste Disposal**, fuel cycle facilities, …

Analysis of Fukushima-Daiichi Accident: SA Progression and Source Terms

Background:

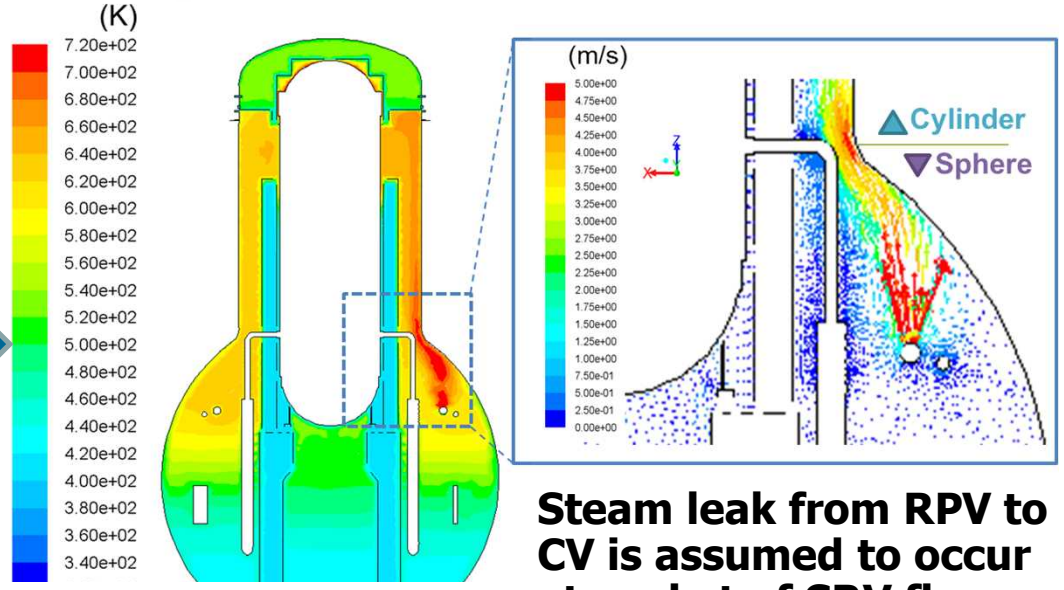
- JNES started the accident analysis with **MELCOR** soon after the accident.
- By using the **source terms with MELCOR**, an **environmental consequence analysis** was done in JAEA.
- **S/NRA/R** is participating in OECD/NEA **BSAF** Project.



M. Hirano, Presented at U.S.NRC RIC2014.

Recent Development:

- Based on the MELCOR results, **CFD** (Computational Fluid Dynamics) calculation for inside the containment is being done to study the **containment failure mechanism and location** at Unit 1.



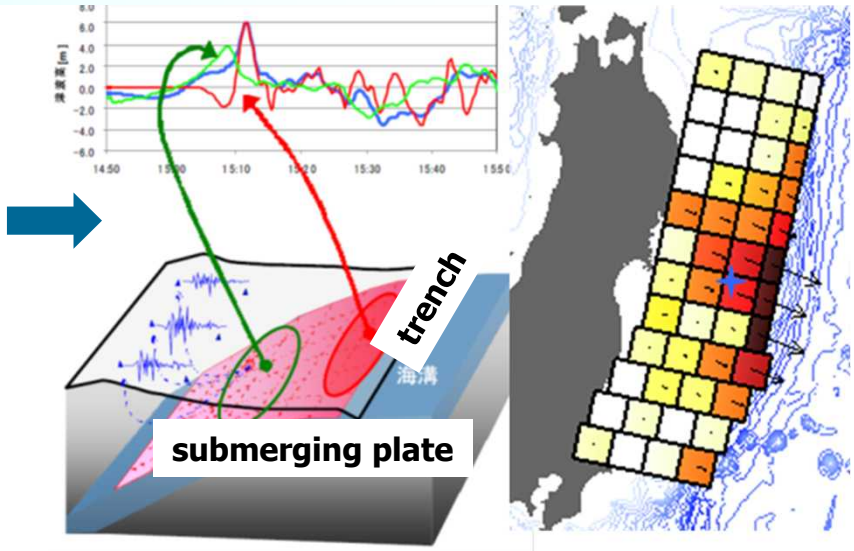
5.4 hours after shutdown

Steam leak from RPV to CV is assumed to occur at gasket of SRV flange.

Research on Extreme Natural Hazards: Tsunami

Hazard evaluation:

- For 2011 Tohoku Earthquake, JNES developed a **tsunami source model**. By generalizing this model, S/NRA/R is developing a **probabilistic tsunami hazard evaluation method**.

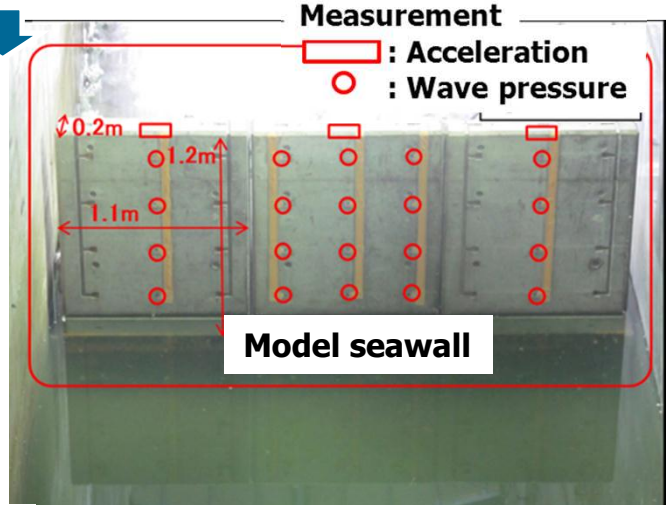


Slips in sub-fault in JNES source model (**Inversion analysis**)

Fragility data accumulation:

- S/NRA/R is conducting **the tests on impact on seawall** due to **tsunami**.

Large Scale Channel Test:
184m x 3.5m (12m in depth)



Model Seawall (1/10 Scale)
1.1m x 1.2m x 0.2m

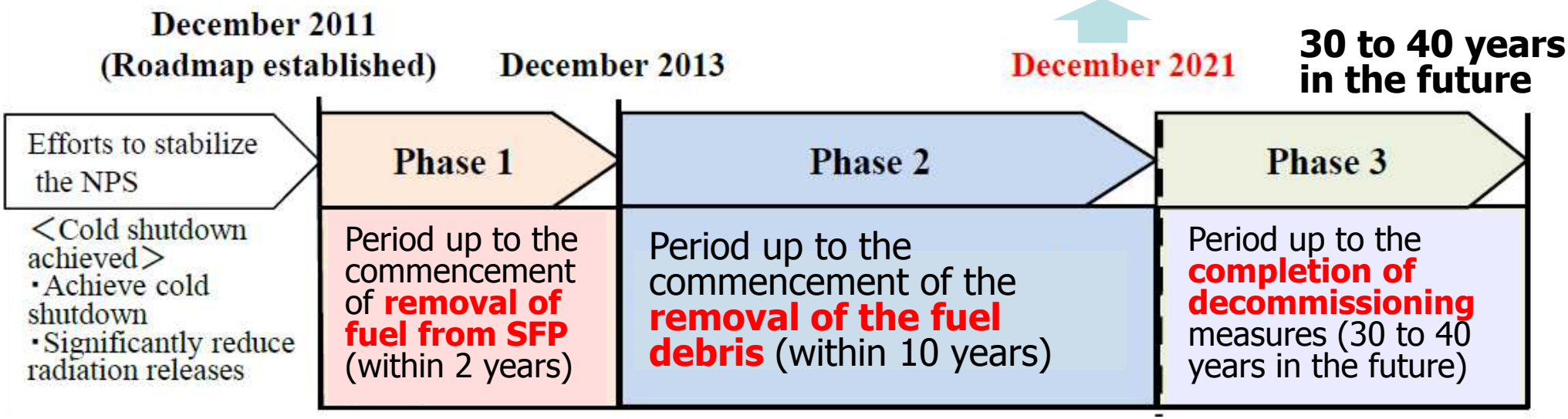
- The tests are being done at PARI (Port and Airport Research Institute) .
- The data obtained are expected to be used for updating the **review guides** for design against tsunami.

Current Status of Fukushima Daiichi

Mid-and-Long-Term Roadmap towards Decommissioning

- In Feb., 2013, the Nuclear Emergency Response Headquarters of the government established the **Council for Decommissioning** of TEPCO's Fukushima Daiichi NPS" (**Chairman: Minister of Economy, Trade and Industry**).
- In **June 2013**, the Council revised the **Mid-and-Long-Term Roadmap***:

First half of FY2020 (one-and-a-half years earlier than the initial plan) at earliest



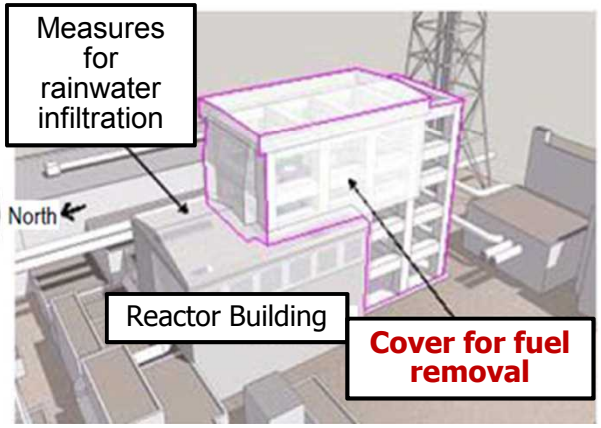
Source below, edited by the author

* Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4
Source: http://www.meti.go.jp/english/press/2013/pdf/0627_01a.pdf

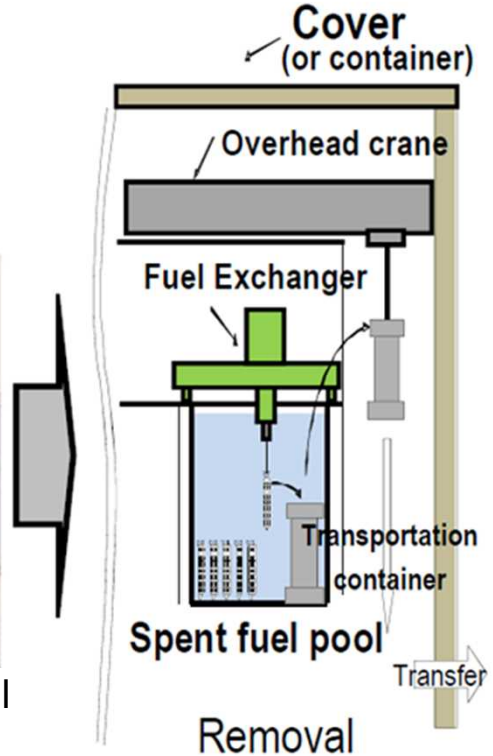
Fuel Removal from Spent Fuel Pools

- Removal of fuel in **Unit 4 SFP** started on **Nov. 18, 2013** and is planned to be completed until end of 2014.
  - Number of fuel assemblies transferred to **common pool**: **1254/1533** (More than**75%** as of Sep. 29, 2014)
- **In Unit 3**, preparatory works are in progress for installing a cover for fuel removal.

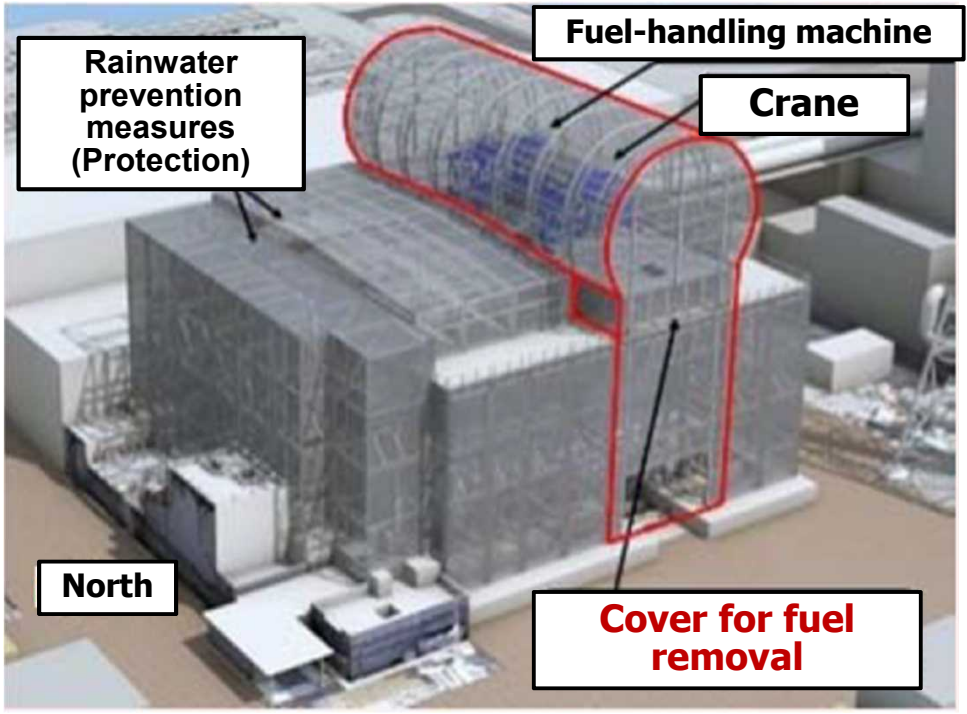
Unit 4



Installation of cover for fuel removal



Unit 3



http://www.tepco.co.jp/nu/fukushima-np/removal4u/index-j.html

Rubble Removal from Unit 3 R/B

March24, 2011

April 19, 2014

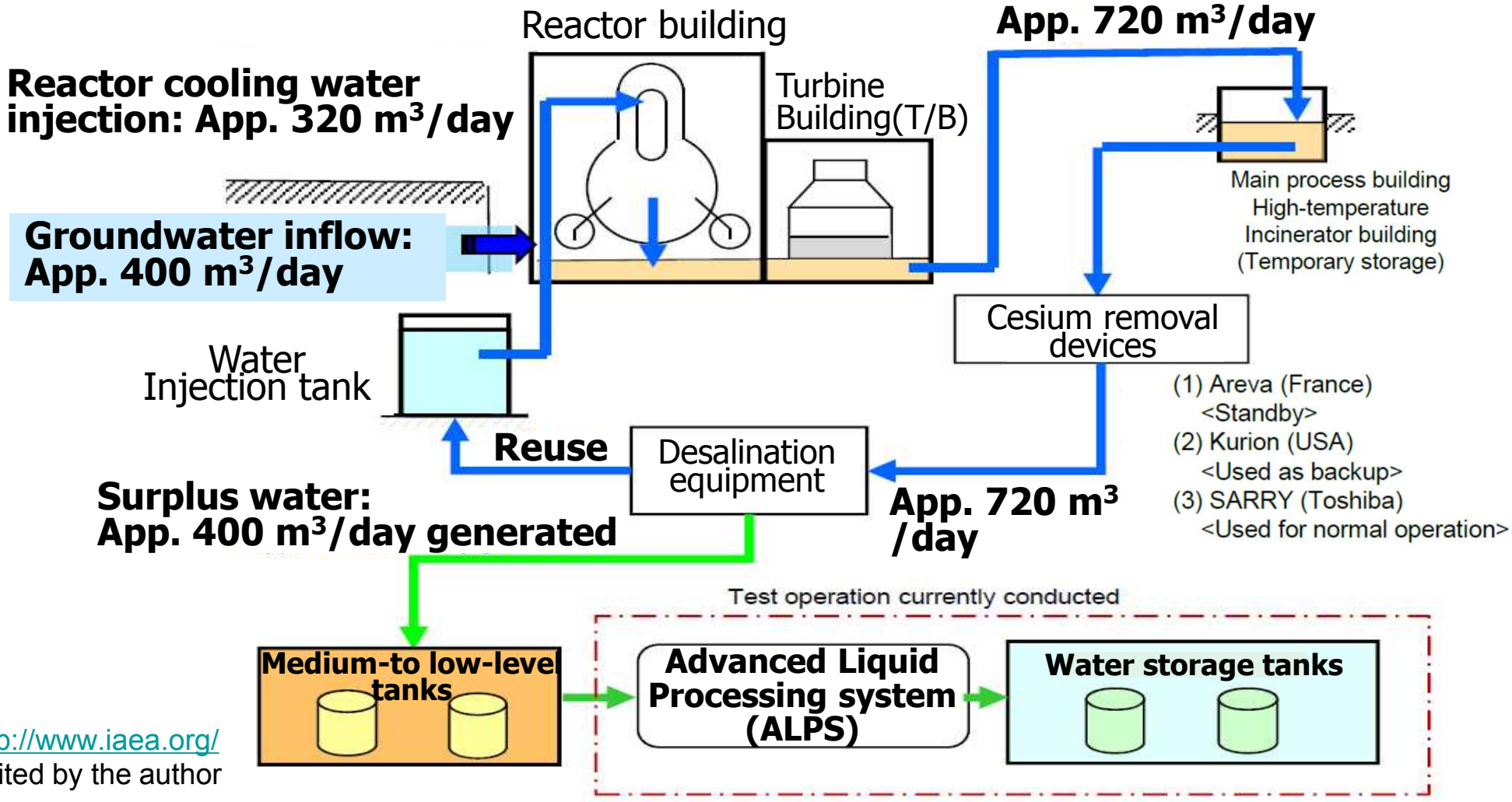
February21, 2012

February25, 2014

Photo taken by TEPCO

Contaminated Water Issue at Fukushima Daiichi

- Contaminated water in T/Bs is treated and injected back to RPVs.
- App. **400m³/day of groundwater** is intruding into TBs and it forces the capacity of tanks increase.



http://www.iaea.org/
Edited by the author

Storage Tanks

- 503,000 m^3 of various levels of radioactive water is stored in the storage tanks.
- 387,000 m^3 out of the total volume is β and low-level Cs water that was treated with reverse osmosis (RO) membrane. It is stored in steel-made cylindrical storage tanks with flange. [July.8]

Cylindrical storage tanks

Square-shaped storage tanks

Horizontal-installation-type storage tanks

http://www.iaea.org/
Edited by NRA

Enhancement of ALPS Capacity

Multi-Nuclide Removal Equipment (ALPS):

- **ALPS** aims to reduce the radioactivity levels of **62 nuclides** in contaminated water to the legal release limit or lower (tritium cannot be removed) to **reduce the risk**.

	Current ALPS	ALPS #2	Advanced ALPS
Capacity	750m³/day	>750m³/day	>500m³/day
Number of systems	3	3	1
Improvement of corrosion resistance	SUS316L	Enameling grade steel	Duplex stainless enameling grade steel
Pretreatment	Flocculation & precipitation	Flocculation & precipitation	Filtration
Facility size (app.)	60m×60m	80m×60m	76m×36m
Expected in-Service Date	2013.3.31～	(2014.10～)	(2014.10～)

- The **second ALPS** and **advanced ALPS** are being installed by TEPCO as well as a subsidy project of the Japanese government.

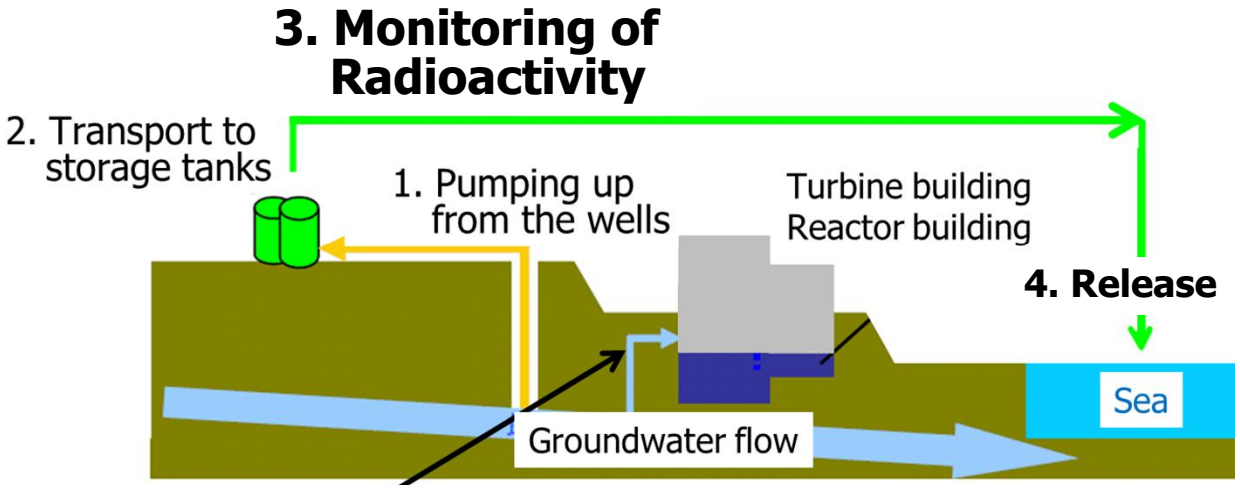
http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/d140828_01-e.pdf

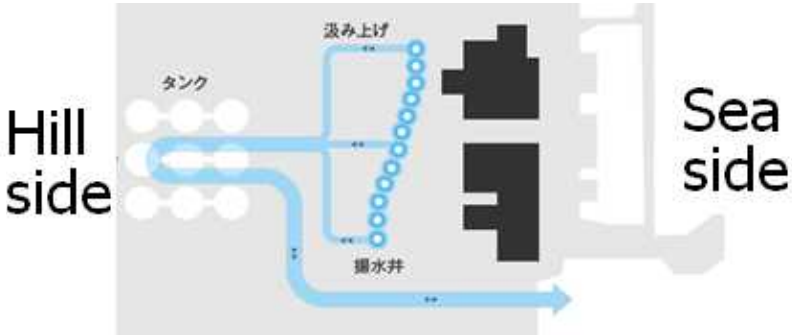
Source: TEPCO

Groundwater Bypass

- In May 2014, TEPCO started **"Groundwater Bypass"** to reduce the amount of groundwater intrusion.
- Groundwater is **pumped up** from the wells upstream of T/Bs and stored in the storage tanks and is **released to the sea after confirming that the radioactivity concentrations** are lower than the prescribed criteria.

Operational Rule:
Cs-134: less than 1 Bq/L
Cs-137 : less than 1 Bq/L
Total β : less than 5 Bq/L
H-3 : less than 1,500 Bq/L
The sum of each ratio of prescribed concentration limit: 0.22





App. 150 m^3/day reduction of groundwater intrusion is expected.

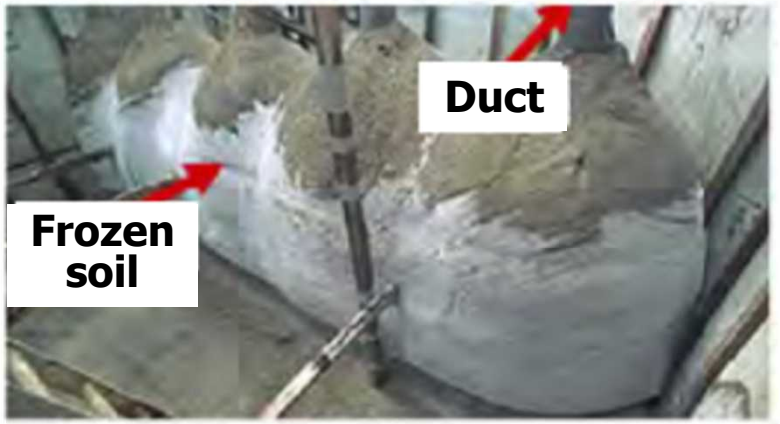
Source TEPCO, Edited by the author

Frozen Soil Wall

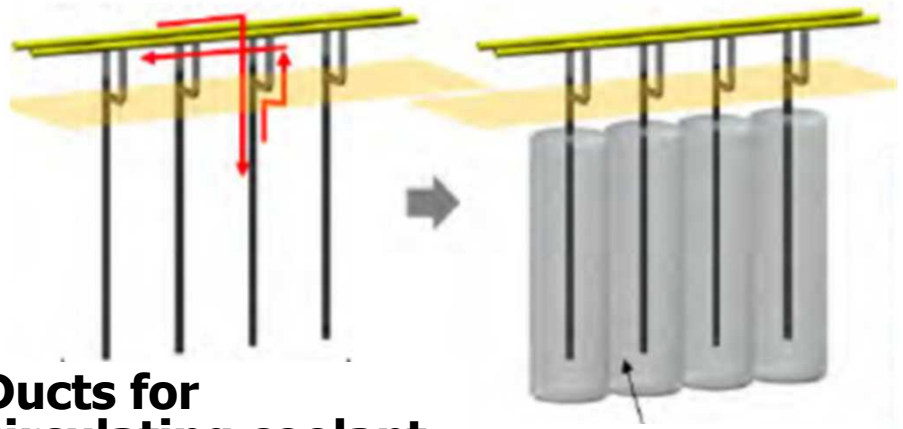
Report from the Committee on Measures related to Contaminated Water Treatment,
The Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant

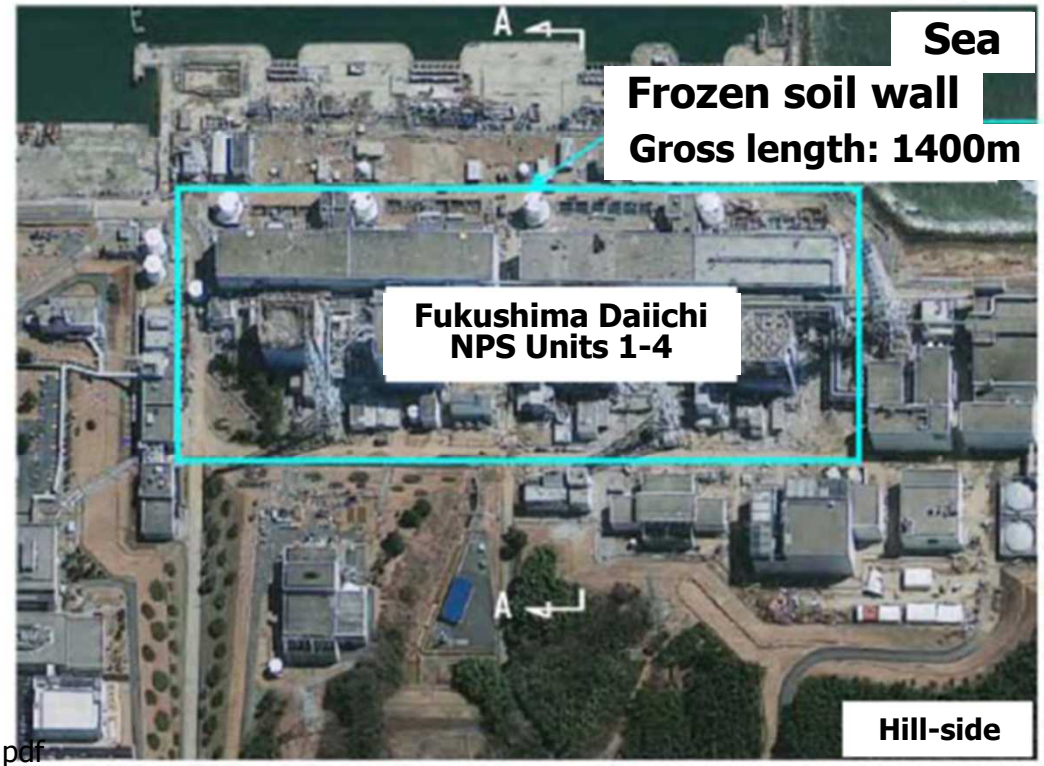
Frozen soil wall:

- Implement the ducts in the ground with a pitch of, e.g. 1m, and circulate coolant.
- Construction already **started in June 2014** and the freezing operation is expected to start within FY2014.



Circulation of Coolant

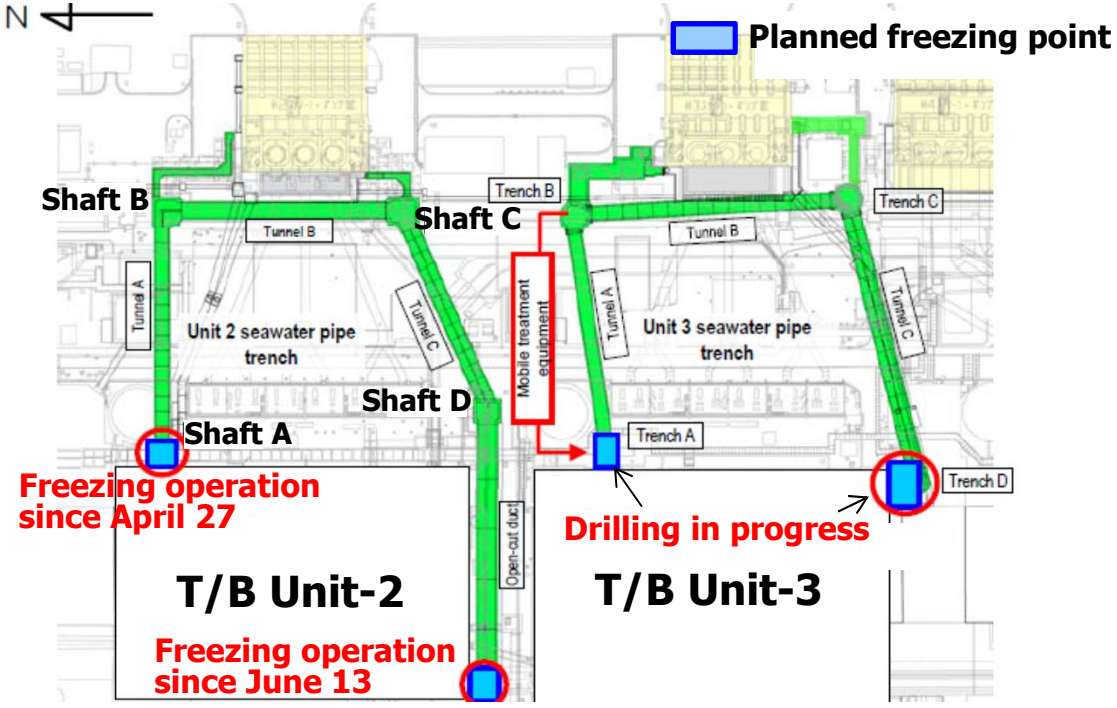




Source below, edited by the author:
http://www.tepco.co.jp/nu/fukushima-np/roadmap/images/t130627_11-j.pdf
http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/d140627_01-e.pdf

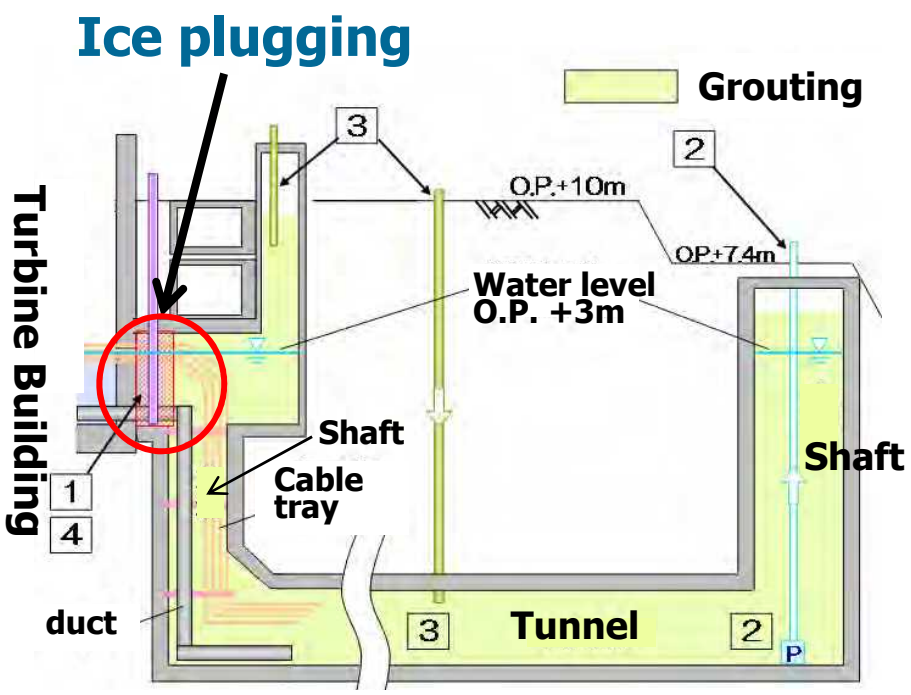
Contaminated Water Remaining in Trenches

- Highly contaminated water remains in the **main trenches** in seaside area. Contaminated water is flowing in from T/Bs.
- TEPCO attempts to drain the water after **plugging the flow paths** by using the similar technique to that to be used for frozen ice wall.



Main trenches and ice plugging operation

Source TEPCO, edited by the author:
http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/d140627_01-e.pdf



Schematic of main trench at Unit 2

Source TEPCO, edited by the author:
http://www.tepco.co.jp/nu/fukushima-np/roadmap/images/t130627_11-j.pdf

Summary

- Based on the lessons learned from the Fukushima Daiichi accident, the NRA was created as **an independent and integrated regulatory body**.
- Since nuclear safety/security are to a great extent **scientific** in nature, "**Technical Independence**" is of utmost importance for regulatory decision-making.
  - The "**Diet's report**", for example, pointed out that "**lack of expertise**" is one of the **fundamental causes** of the accident.
- **JNES was merged with NRA** to enhance the technical expertise and "**S/NRA/R**," an **internal TSO**, was created.
- Regarding Fukushima Daiichi, various activities such as fuel removal from SFP are in progress according to **"Mid-and-Long-Term Roadmap towards Decommissioning"**.
  - Large amount of radioactive water being created daily is a difficult issue that needs long-term efforts.
  - Currently, removal of **highly radioactive water reaming in the trench** is a high priority issue.

Challenges as a TSO

- **TSO** needs to timely contribute to resolving **regulatory issues** with high priority and, at the same time, be **vigilant** and **proactive** to **new findings / emerging future needs**.
  - ➡ **Effective Safety Research** plays a key role.
- Maintaining **"technical infrastructure"** is a challenge.
  - Continuous recruiting / developing **skilled research engineers**,
  - Maintaining **test facilities**, **hot laboratories**, etc.
  - Glowing needs for natural sciences such as seismology, meteorology, volcanology, etc. TSO needs to have an **"interface function"** with **natural scientists** in academia, etc.
- **International information exchange** and **joint research projects** in IAEA, OECD/NEA, ETSON, etc. are playing an essential role.
- **Communication** between **regulatory body** and **industries** on research be promoted while taking into due account of regulatory independence.

Appendix

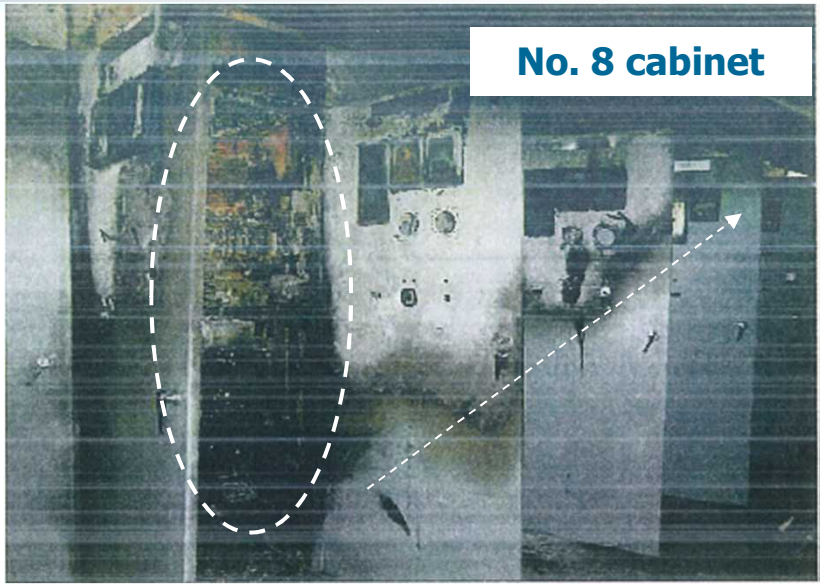
New Regulatory Requirements: Basic Policy

- Place emphasis on **Defense-in-Depth** (DiD)
  - Prepare multi-layered protective measures and, for each layer, achieve the objective only in that layer regardless of the measures in the other layers.
- Eliminate **common cause failures**
  - Strengthen **fire protection** and measures against **tsunami inundation**.
  - **Enhanced reliability of SSCs** important to safety (eliminate shared use of passive components, if relied on for a long time).
- Assess and enhance protective measures against **extreme natural hazards**
  - Introduce conservative/robust approaches in assessment of earthquake and tsunami and measures against tsunami inundation.
  - Make much account of "**diversity**" and "**independence**", shifting from "**redundancy centered**".
- Define "**performance/functional" requirements**
  - **Provide flexibility** in choosing **acceptable measures**.

Fire Safety Research on HEAF: High Energy Arcing Fault

Appendix

- At **Onagawa-1**, fire took place due to short circuit inside **MC** during the 2011 Tohoku Earthquake.
  - **High energy gas** generated by **arcing fire** was **propagated to the other cabinets** through the control cable duct.
  - **In 2012**, JNES started **HEAF tests** at U.S. KEMA and **S/NRA/R** continues them.



Source: Tohoku Electric Power, May 2011, http://www.nsr.go.jp/archive/nisa/earthquake/files/houkoku230530-2.pdf

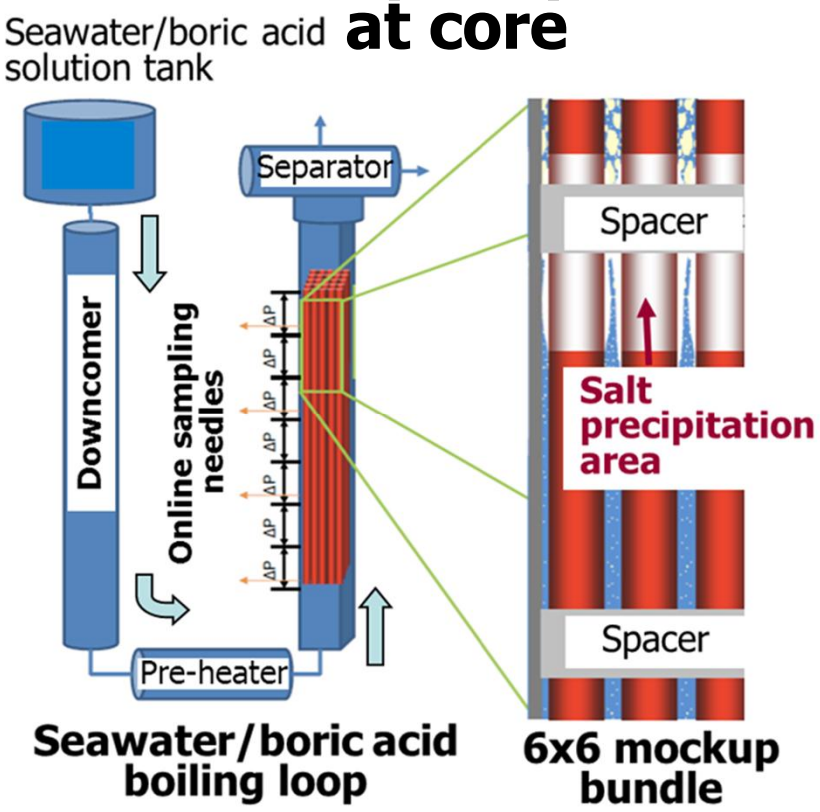
HEAF simulation Test at KEMA in U.S.

- Currently, **S/NRA/R** is actively participating in the OECD/NEA international joint projects, **PRISME-2** and **HEAF**.
- The acquired data have been used for developing the **Review Guides for Fire Protection** and **Fire Hazard Analysis** for the new regulatory requirements.

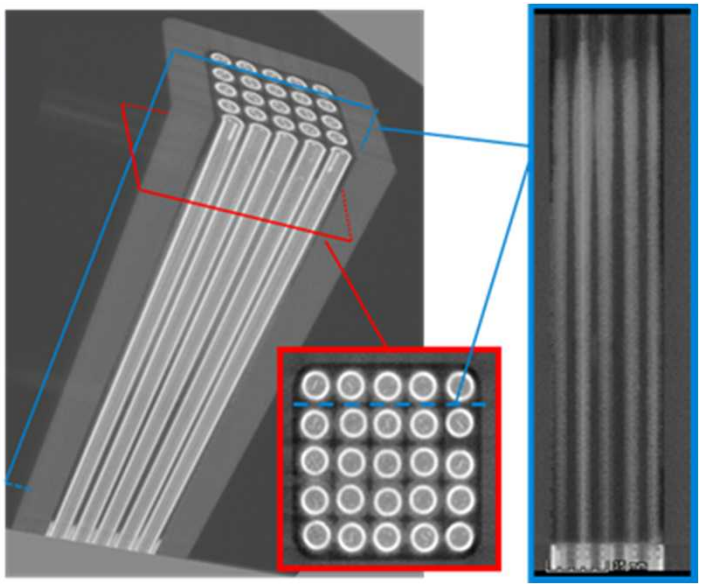
Appendix Experimental Study on Seawater and Boric Acid Injection

- We conducting a study on seawater/boric acid injection to identify the **salt and boric acid crystallization/precipitation** characteristics and its **influence on fuel/debris cooling** such as **flow blockage** for improving AM measures.

Test for precipitation at core



Appearance of salt crystallization in a preliminary test with simple geometry



Preliminary test with bundle

Cross-sectional view at TAF-15mm

Vertical-sectional view