Keynote Presentation

Summary on Fukushima Related Activities in Japan

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Contents

- **Overview**
  - Current Status of Safety Regulation

- **Creation of NRA**
  - Technical Independence
  - Merger of JNES with NRA
  - New Regulatory Requirements
  - Safety Research

- **Current Status of Fukushima Daiichi**
  - Fuel Removal from Spent Fuel Pools
  - Contaminated Water Issues

- **Summary and Challenges as a TSO**
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)

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.

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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)

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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

- 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

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.

IAEA SF-1

IAEA Safety Standards, etc.

Requirements for B-DBA

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

**Pre-existent**

- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs
- Seismic/Tsunami resistance

**New**

- Suppression of radioactive materials dispersal
- Specialized Safety Facility
- Prevention of CV failure
- Prevention of core damage
- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs
- Seismic/Tsunami resistance

**4th Layer of DiD**

**3rd Layer of DiD**

(Severe Accident Measures) NEW

Reinforced

Reinforced
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

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.
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 example, one filtered venting for prevention of containment failure and another filtered venting of Specialized Safety Facility are acceptable solutions.

Filtering 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 solutions.

* System configuration is an example.
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.

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.

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

Fragility data accumulation:
- S/NRA/R is conducting the tests on impact on seawall due to tsunami.

- 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.

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

Model Seawall (1/10 Scale) 1.1m x 1.2m x 0.2m
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
- Period up to the commencement of the removal of fuel debris (within 10 years)
- Period up to the completion of decommissioning measures (30 to 40 years in the future)

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
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.

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**Unit 4**

- Measures for rainwater infiltration
- Reactor Building
- Cover for fuel removal
- Installation of cover for fuel removal

**Unit 3**

- Rainwater prevention measures (Protection)
- Fuel-handling machine
- Crane
- Cover for fuel removal

Rubble Removal from Unit 3 R/B

March 24, 2011

April 19, 2014

February 21, 2012

February 25, 2014

Photo taken by TEPCO
Contaminated water issue at Fukushima Daiichi

- Contaminated water in T/Bs is treated and injected back to RPVs.
- App. 400 m$^3$/day of groundwater is intruding into TBs and it forces the capacity of tanks increase.

Groundwater inflow: App. 400 m$^3$/day
Reactor cooling water injection: App. 320 m$^3$/day
Surplus water: App. 400 m$^3$/day generated

Cesium removal devices
1. Areva (France) <Standby>
2. Kurion (USA) <Used as backup>
3. SARRY (Toshiba) <Used for normal operation>

Advanced Liquid Processing system (ALPS)
Medium-to low-level tanks
Water storage tanks
503,000 m³ of various levels of radioactive water is stored in the storage tanks.

387,000 m³ 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]
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.

<table>
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<th>Current ALPS</th>
<th>ALPS #2</th>
<th>Advanced ALPS</th>
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<tbody>
<tr>
<td>Capacity</td>
<td>750m³/day</td>
<td>&gt;750m³/day</td>
<td>&gt;500m³/day</td>
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<tr>
<td>Number of systems</td>
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<td>1</td>
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<td>Improvement of corrosion resistance</td>
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<td>Enameling grade steel</td>
<td>Duplex stainless enameling grade steel</td>
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<td>Pretreatment</td>
<td>Flocculation &amp; precipitation</td>
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<td>Filtration</td>
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<td>80m×60m</td>
<td>76m×36m</td>
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<tr>
<td>Expected in-Service Date</td>
<td>2013.3.31～</td>
<td>（2014.10～）</td>
<td>（2014.10～）</td>
</tr>
</tbody>
</table>

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

Source: TEPCO

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 m³/day reduction of groundwater intrusion is expected.
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.

Source below, edited by the author:
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**


**Schematic of main trench at Unit 2**

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

- 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.

- 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.

We are 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