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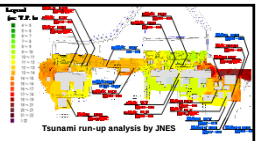
Incorporated Administrative Agency
Japan Nuclear Energy Safety Organization:
Japanese TSO for Safety Regulation


Tsunami run-up analysis by JNES

Post-Fukushima Safety Research in Japan

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Outline

- **Overview**
  - Current Status of Fukushima Daiichi NPP and Nuclear Power in Japan
- **Safety Research with Short-term Needs**
  - Seismic and Tsunami Hazard Evaluation
  - Upgrading of SA Progression and Source Term Analysis
  - Upgrading of Accident Management Measures
  - Hydrogen Mixing and Detonation Behavior
  - Environmental Consequence Analysis (Level 3 PSA)
- **Summary: Post-Fukushima Safety Research Needs and Priorities**

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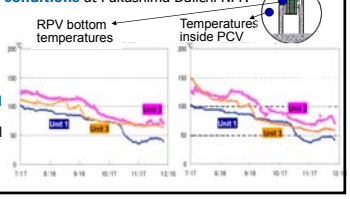
Overview of Current Status (1/2)

- **Stress test is in progress:**
  - Only **2 units** are in operation while the rest of 52 units are in shutdown. (as of Feb. 21, 2012) Three relevant ministers decided the test be a necessary condition for restarting.
  - A total of **16 units** have submitted the stress test results to NISA. (as of Feb. 17, 2012)
- **Reform of regulatory framework will be taken place:**
  - On Aug. 15, 2011, the Cabinet made decision to create a new regulatory body as an external agency of the Ministry of the Environment, in **April 2012**. Relevant part of NISA and the function of NSC will be merged.
- **On Dec. 16, 2011,** the Government declared the **completion of roadmap towards restoration from accident conditions** at Fukushima Daiichi NPP.
  - Stable core cooling has been established. Leaked / accumulated water is processed and injected back into the RPVs.
  - All the temps measured at RPV bottom and inside PCV became well below 100°C. The radiation dose at the site boundaries due to additional release is assessed to be 0.1mSv/y.



TEPCO Press Release (Nov. 17,2011)

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Overview of Current Status (2/2)

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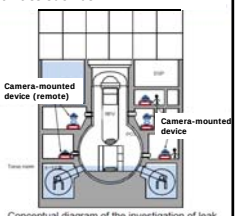
- On Dec. 21, 2011, the government and TEPCO jointly set forth **the mid-and-long-term roadmap towards decommissioning** of Fukushima Daiichi Units 1-4:
  - Phase 1: to start **removal of fuel from SFPs within 2 years**
  - Phase 2: to start **removal of fuel debris within 10 years**
  - Phase 3: **decommissioning in 30 – 40 years**
- This roadmap includes various specific plans for R&D activities such as:
  - Remote decontamination of R/B interior
  - Technologies for **identification of leak areas** in PCV and investigation of PCV interior
  - PCV repair technologies

An example:
R&D for **identifying the leak areas in PCV**

Reference: http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/111221e14.pdf



Conceptual diagram of the investigation of leak areas in the PCV

- It is expected that indispensable information could be obtained from the viewpoint of further event investigation and also SA progression and source term evaluation.

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Safety Research with Short-term Needs
- Seismic and Tsunami Hazard Evaluation – (1/2)

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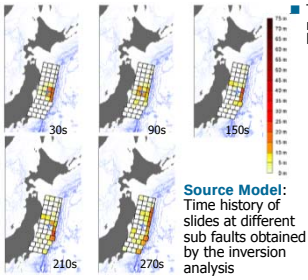
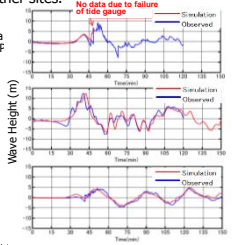
- JNES estimated a **tsunami source model** through **joint inversion analysis** based on references [1] and [2], as well as the characteristics of the tsunami resulted from the Tohoku earthquake. The source model includes the source rupture process.
- Then, JNES conducted a **tsunami propagation analysis** by using the source model.



Source Model: Time history of slides at different sub faults obtained by the inversion analysis

- The observed tsunami waveforms were well reproduced not only at Fukushima Daiichi site but also other sites.



[1]: Tsunami source model (Ver. 4.2)(Fujii and Satake, 2011), http://iisee.kenken.go.jp/staff/fujii/Off tohoku-pacific2011/tsunami_ja.html
[2]: Tsunami simulation for the Tohoku Distrid-Off the Pacific Ocean Earthquake (Tohoku University Model)
http://www.tsunami.civil.tohoku.ac.jp/hokusai3/

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Safety Research with Short-term Needs
- Seismic and Tsunami Hazard Evaluation – (2/2)

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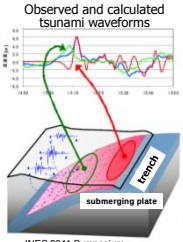
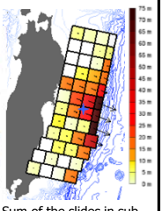
- In this area, urgent research is required, based on the knowledge and experience gained from the present tsunami, for development of:
  - **Methods for tsunami source model**, and
  - **Guides for design basis tsunami height** by using **probabilistic hazards assessment methodology.**
- **Rupture process** is one of the keys:
  - The inversion analysis by JNES showed that the slide expanded from original rupture area to somewhat deeper areas, and moved to shallow areas along the trench, where the max. slide displacement was more than 70m.
  - The timing and time duration of rupture at each sub fault have large effects on the tsunami waveforms.

Reference: Additional Report of the Japanese Government to the IAEA, Sept. 2011

Observed and calculated tsunami waveforms



JNES 2011 Symposium, Dec. 22, 2011



Sum of the slides in sub fault in JNES source model (Inversion analysis)

- Regarding safety assessment such as tsunami PSA, further R&D may be needed:
  - Development of methods and models to evaluate dynamic **tsunami wave force** that impacts structural integrity / water tightness.

Safety Research with Short-term Needs
- Upgrading of SA Progression and Source Term Analysis -

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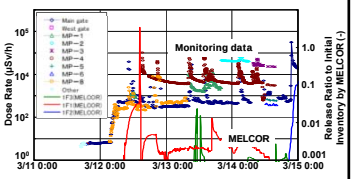
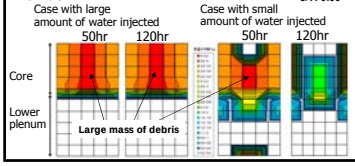
- Fukushima accident analysis **with MELCOR in JNES**:
  - Overall trends of the plant data during the accident were reproduced reasonably well by MELCOR as presented at the IAEA Ministerial Conference in June 2011.
  - Onsite monitoring data, that may indicate **source term**, are also reproduced relatively well.
  - However, fuel melt progression depends largely on the amount of water injected and other factors. Reliable prediction of the **debris distribution within RPV and PCV** is difficult [1].



Unit 3



- **TEPCO's analysis with MAAP**[2]:
  - 100%, 57% and 63% of total fuel debris exists on the pedestal region in PCV in Unit 1, 2 and 3, respectively.
  - Max. penetration depth into concrete is 0.65m.

[1]: http://www.nisa.meti.go.jp/shingikai/700/12/001/1-6-1.pdf
[2]: http://www.nisa.meti.go.jp/shingikai/700/12/001/1-5.pdf

Safety Research with Short-term Needs
- Upgrading of Accident Management Measures -

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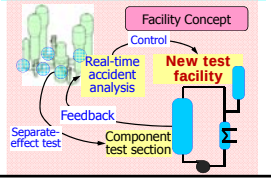
- JAEA is a R&D organization under MEXT. The mission of the Nuclear Safety Research Center in JAEA is to contribute to enhancement of safety by supporting safety regulation.

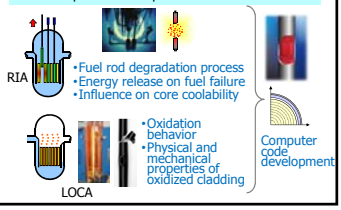
Thermal-Hydraulic Safety Research

- Clarify accident causes and detailed consequences under beyond-DBEs
- Confirm effectiveness of safety features against prevention & mitigation of SA
- Prepare own prediction methods to demonstrate prototypical accident phenomena with high accuracy
  - Development of new test facility
  - Development and V&V of BE methods



Fuel Safety Research

- Evaluate behavior and marginal performance of fuel under beyond-DBE conditions
  - Irradiation tests at NSRR with high enthalpies
  - Oxidation tests of the cladding under various severe loss-of-coolant conditions
  - Characterization of damage fuel rod components
  - Development of computer codes



Safety Research with Short-term Needs
- Hydrogen Mixing and Detonation Behavior -

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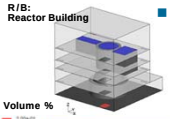
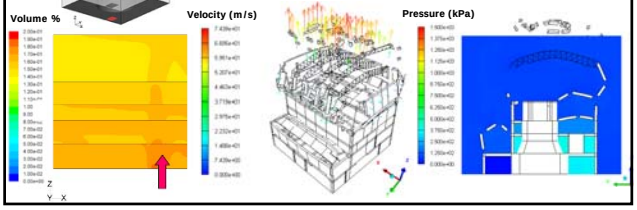
- JNES is conducting analyses of **hydrogen mixing and detonation in R/Bs**:
  - MELCOR for hydrogen source evaluation, FLUENT (CFD code) for hydrogen transport and mixing, and AUTODYN for structural analysis of detonation.
  - The **objectives** are to better understand the phenomena that took place in Unit 1 and 3, and **to assess and improve the methods and tools**.



- Some results from **the analysis of detonation at Unit 3**:
  - The amount of H_2 leaked into R/B is estimated to be app. 1 ton.
  - If it is assumed that the leakage took place at S/C, namely, lower part of R/B, overall detonation behavior is well reproduced.



Safety Research with Short-term Needs
- Environmental Consequence Analysis (Level 3 PSA) -

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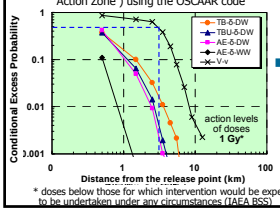
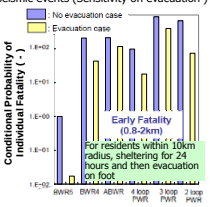
- Level 3 PSA is a useful tool to evaluate not only individual risks but also radiological impact on environment and it becomes more and more important after Fukushima.
- **JNES** has developed level 3 PSA method based on the MACCS code, developed by USNRC, to support safety regulation in the areas of **seismic risk evaluation** and **safety goal**, **emergency preparedness**, and so forth.
  - Some study has already been started for application to seismic risk evaluation of **multi-unit site**.

Evaluation for radius of PAZ (Precautionary Action Zone) using the OSCAAR code



* doses below those for which intervention would be expected to be undertaken under any circumstances (IAEA BSS)

Radiological consequence analysis for seismic events (Sensitivity on evacuation)



- **JAEA** has developed the OSCAAR code and applied it to studies on emergency preparedness [1].
  - PAZ for the representative accident scenarios was evaluated to prevent severe deterministic health effects by keeping action level of doses to red marrow.
  - Maximum radius of PAZ was approximately 3km for the accident scenario of ISLOCA(V-v).

[1]: IAEA Safety Standards Series No. GS-R-2, "Preparedness and Response for a Nuclear or Radiological Emergency".

Summary:
Post-Fukushima Safety Research Needs and Priorities

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- It is necessary to fully learn the lessons from Fukushima and feed them back to construct new system pursuing "continuous improvement".
  - As written in the report to the IAEA Ministerial Conference in June 2011, **PSA has not always been effectively utilized** …. While a quantitative evaluation of risks associated with rare events such as a large-scale tsunami is difficult and the uncertainties are large, **Japan has not made efforts to reduce the uncertainties** by explicitly expressing its existence.
  - In short term, some research areas with high priority are:
    - ✓ Development of probabilistic **external hazard evaluation** methods,
    - ✓ Upgrading of **SA and source term evaluation methods and tools**, and
    - ✓ Application of **level 3 PSA** to various areas incl. emergency preparedness.
  - In mid term, it is expected that important information for research will be indentified through R&D activities at the damaged units, such as leak locations at CVs and distribution of fuel material inside RPVs and CVs.
- Declining **technical infrastructure** could have been a contributing factor.
  - **Human resources development** is an urgent issue. Safety research needs to contribute to maintaining the technical expertise / competence.
- The AEC has stared revising the Framework for Nuclear Energy Policy. The existing plans / programs for developing new and advanced reactors would be reexamined.