INL/MIS-23-71837-Revision-0

Current status of cooperation for the Light-Water Reactor R&D Sub-WG PRA

March 2023

Curtis L Smith

Changing the World's Energy Future

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US-Japan
BLC-CNWG

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Light-Water Reactor R&D Sub-Working Group

Probabilistic Risk Assessment

- Risk-Informed Systems Analysis
- Nonlinear Seismic Analysis

4. PRA/Risk-Informed Systems Analysis - Overview

- Risk Informed System Analysis (RISA) is an advanced PRA approach enabled by modern tools and methods which, like typical PRA, characterizes a probability of failure for a given scenario but, unlike conventional PRA, also characterizes the margin to failure for a given scenario.

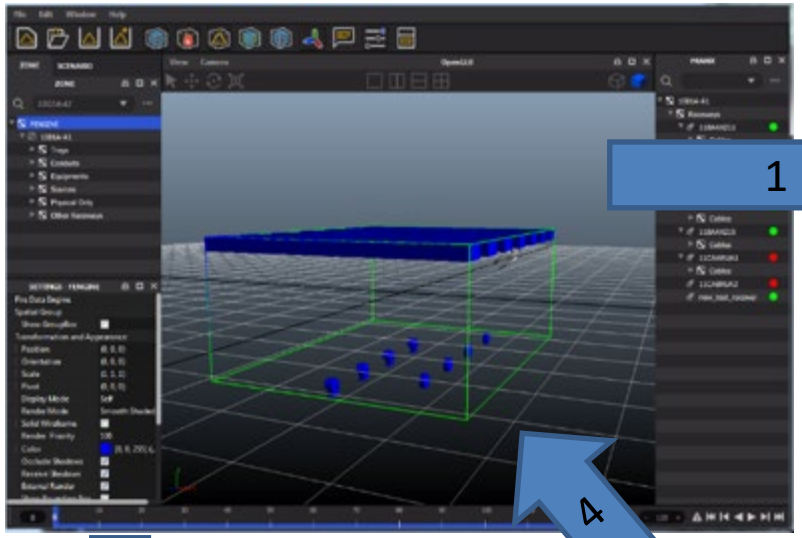
- Changes in the U.S. Light Water Reactor Sustainability program resulted in R&D focus evolving from addressing flooding and seismic risks to economics and safety (with some research on internal hazard risk analysis).

- As a result, topics and an approach for the future INL-CRIEPI/NRRC RISA collaboration to realize realistic internal hazard PRA technology for both countries newly setup as follows.
  - To share the information on internal fire and flooding PRA
  - To update fire risk modeling generic data and models for enhanced fire PRA
  - To improve fire modeling of physical phenomena and the human element

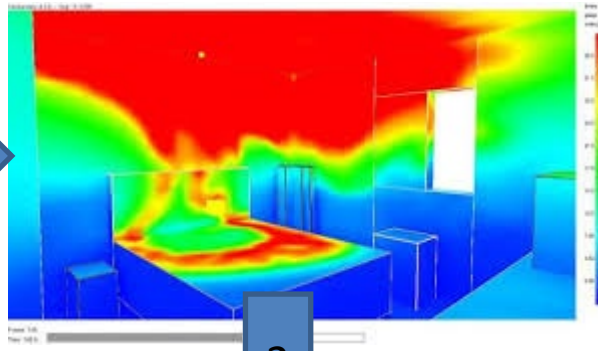
4. PRA/RISA - Fire Modeling (1/3)

US-Japan BLC-CNWG

FRI3D Model

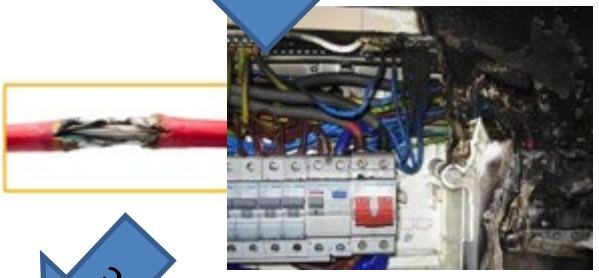


Physics Sim (CFAST/FDS/BRI2002)



1

2



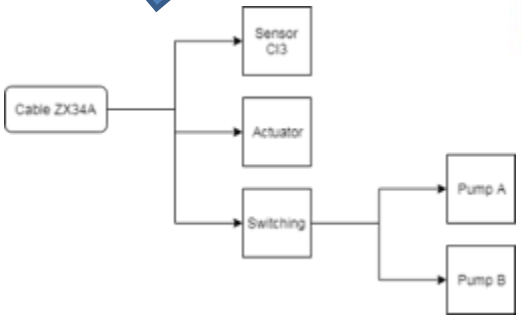
3

Direct Component Failures

(Heat Soak or THIEF calcs)

4

5



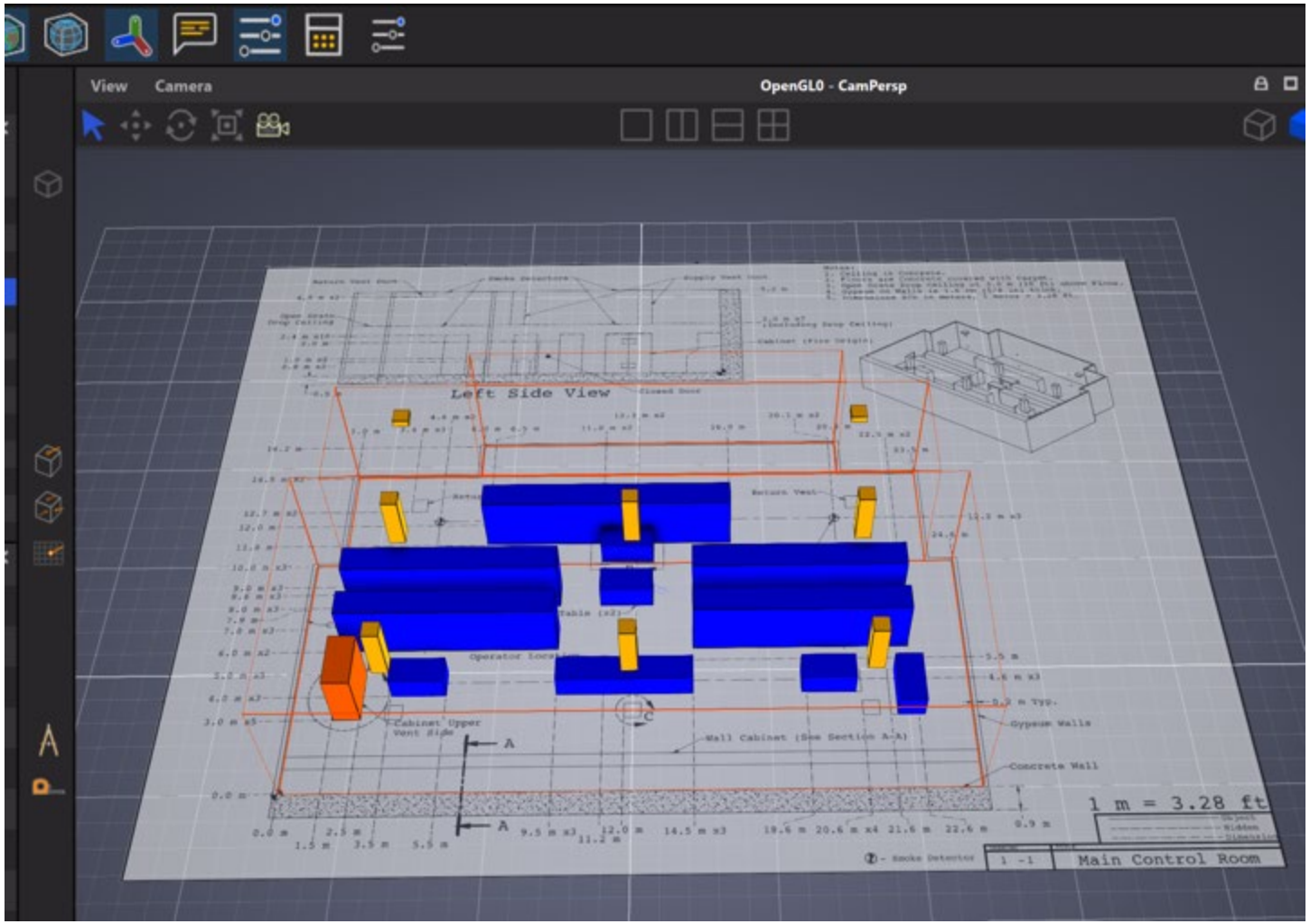
Circuit Analysis For Disabled Components

Result Probability

Enhanced fire PRA platform developed by INL

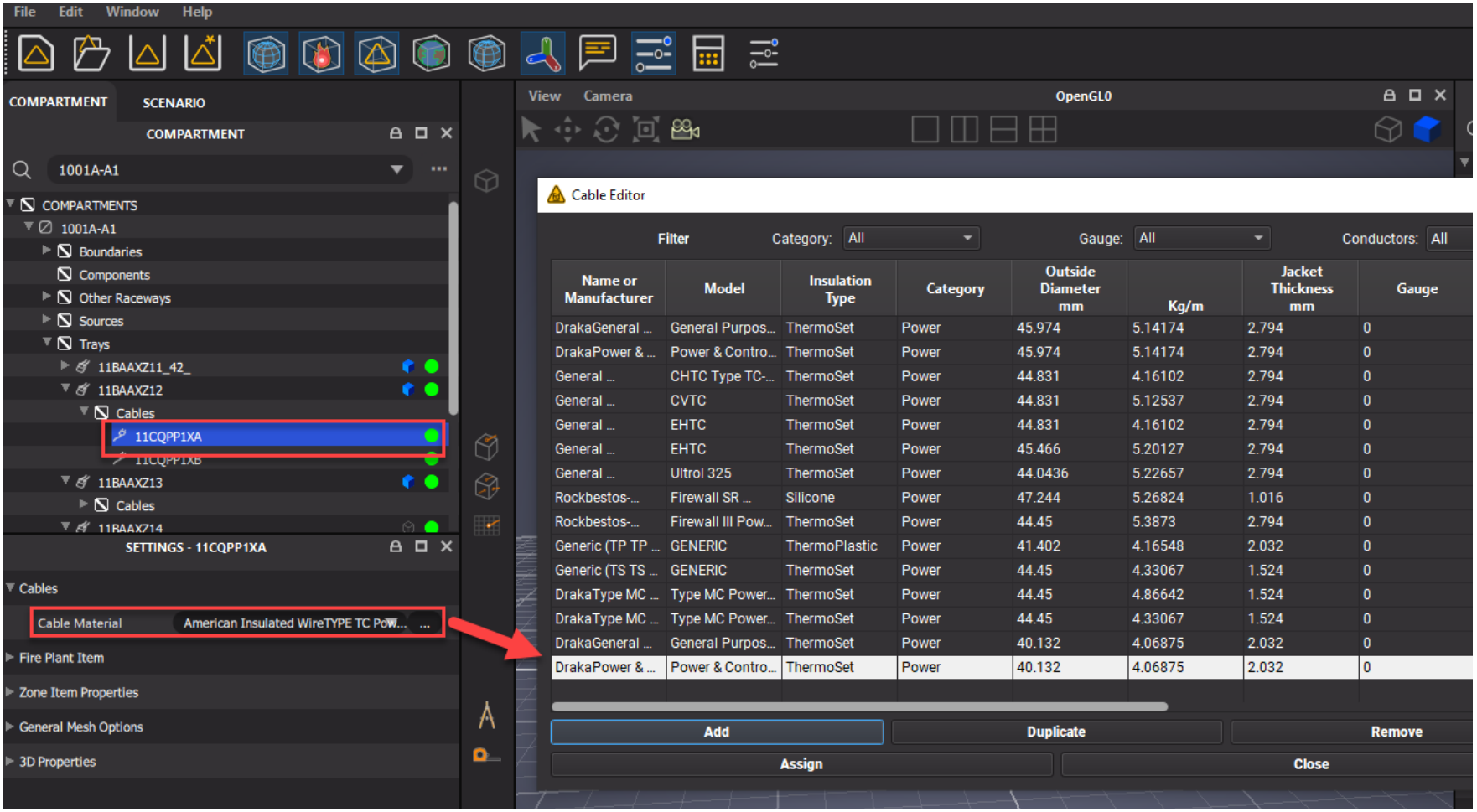
4. PRA/RISA - Fire Modeling (2/3)

- Ability to simply the fire analysis flow, allowing use of Japan or U.S. fire modeling tools



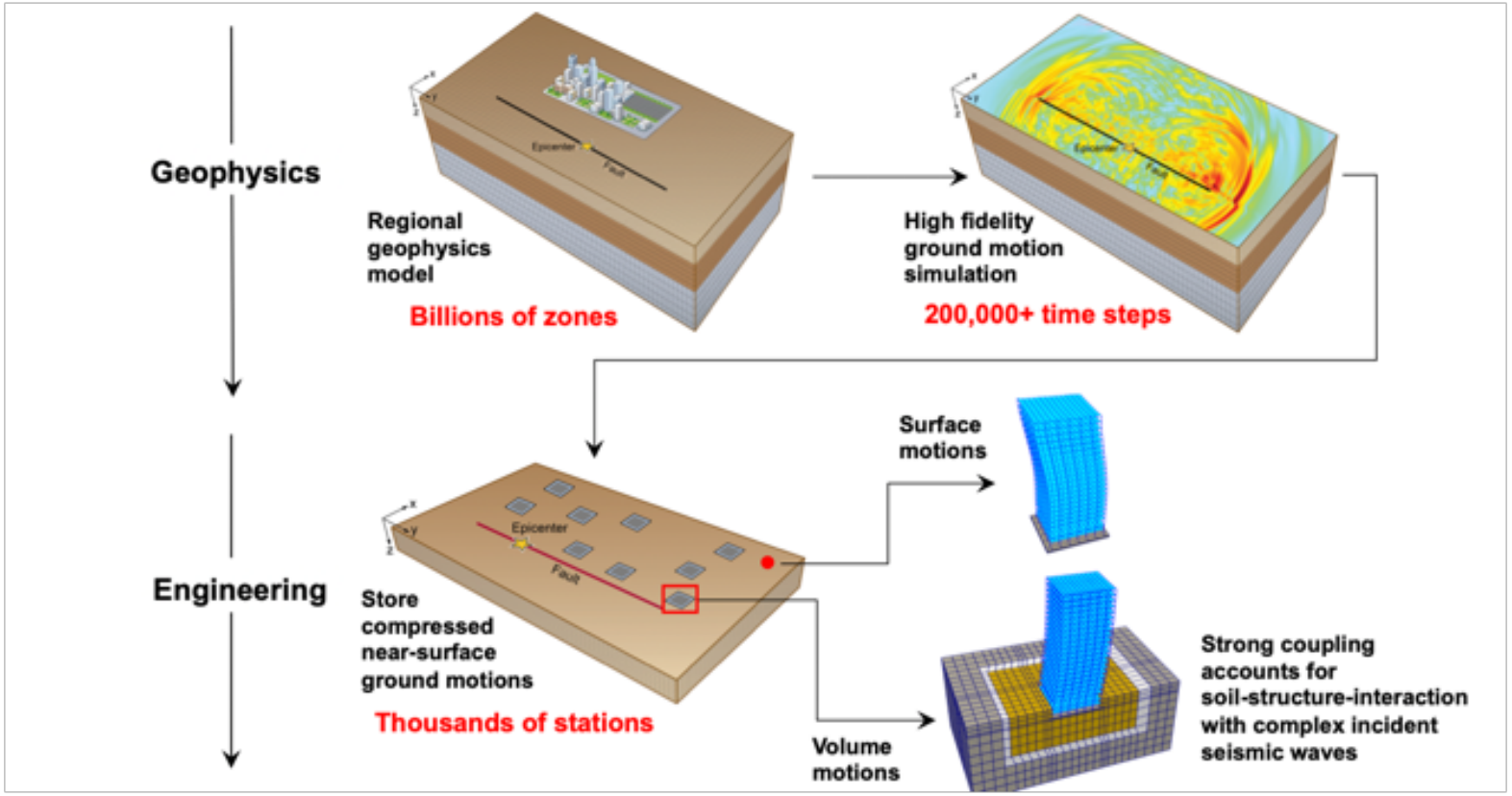
4. PRA/RISA - Fire Modeling (3/3)

- Ability to assign specific cable types and to define new cable specifications, allowing flexibility in modeling



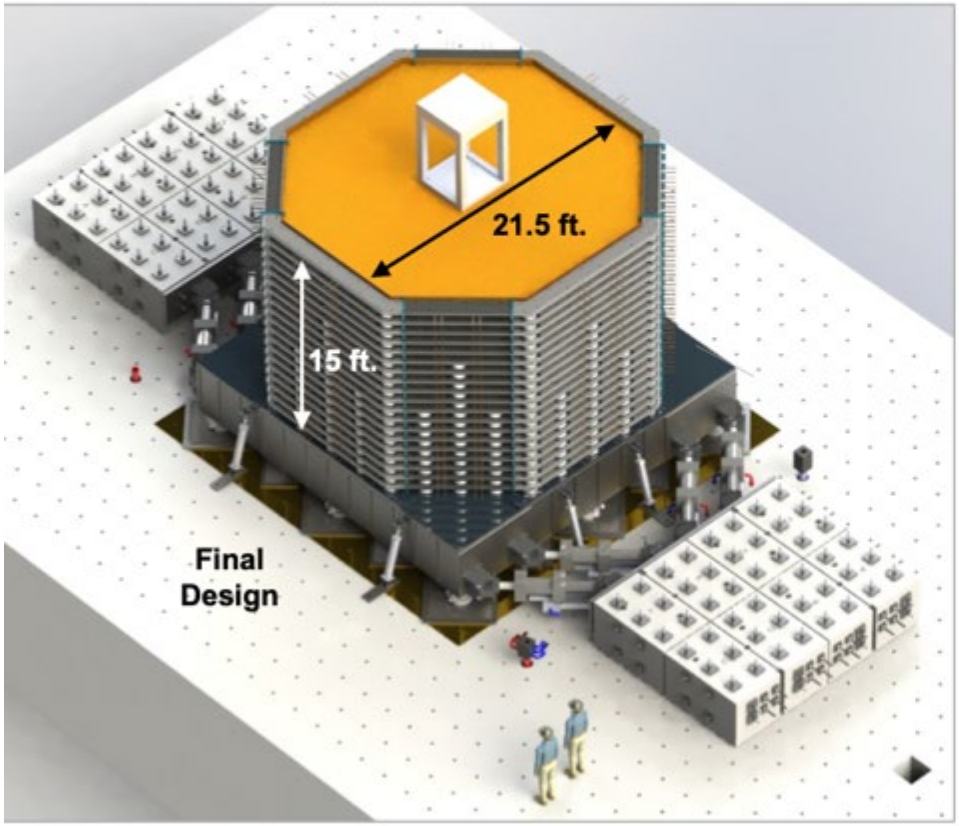
4. PRA/ Nonlinear Seismic Analysis for Advanced Earthquake Simulations Objective – Overview (1/4)

The DOE Exascale Computing Project (ECP) is developing the EQSIM fault-to-structure simulation framework for rigorous coupling of regional geophysics and local engineering soil/structure codes.



4. PRA/ Nonlinear Seismic Analysis for Advanced Earthquake Simulations – Overview (2/4)

The DOE Large-Scale Laminar Soil Box is in the final stage of construction with the completion of the hydraulic system. This experimental facility will be available for testing the effects of soil-structure-interaction and validating computational models.



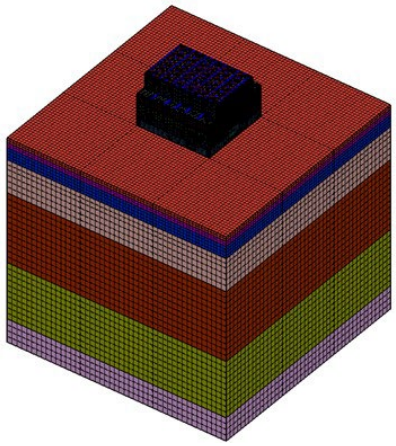
4. PRA/ Nonlinear Seismic Analysis for Advanced Earthquake Simulations – Overview (3/4)

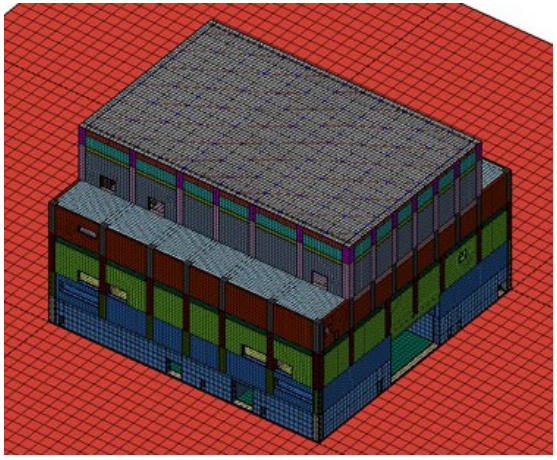
US-Japan BLC-CNWG

Japan model – e-FrontISTR program (developed in 2017 - present)

Key Features of e-FrontISTR

- Fastest and largest in class of numerical analysis program for soil-structure interaction
- Implementation of advanced concrete and soil tensorial constitute relation



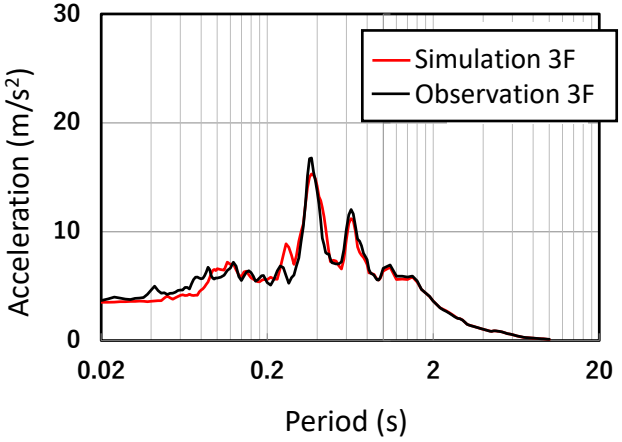


New analysis model of Kashiwazaki-Kariwa Unit 7 R/B

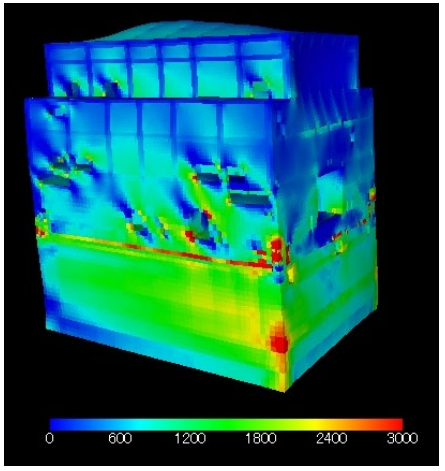
A new analysis model of high fidelity was constructed for Kashiwazaki-Kariwa Unit 7 R/B. It is shown that this model can reproduce observed data in 2007 Niigata-ken Chuetsu-Oki Earthquake.

Characteristics of the analysis model

Node	Element
523,058	330,388



Comparison of observed and simulated acceleration spectra



Max. principal stress

4. PRA/ Nonlinear Seismic Analysis for Advanced Earthquake Simulations – Overview (4/4)

Summary/Impact

- Transitioning to advanced, more realistic computational tools that can rigorously support risk-informed, performance-based evaluations will be a major advancement in the ability to ensure appropriate seismic safety of nuclear facilities.

- The ability to collaboratively test, analyze and validate respective advanced software codes is essential to confidence building and ultimate acceptance of advanced simulation tools, the new soil box experimental capability will provide a unique opportunity for cooperative code validation.

- Both the U.S. and Japan industry and governmental organizations will benefit from the development of a simulation technology base for advanced risk-informed, performance-based analysis and design of nuclear systems.