



# Accelerating Innovation by Integrating Advanced Modeling, Simulation, and Experimentation

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U.S. DEPARTMENT  
of ENERGY

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# The challenges associated with high-burnup fuel fragmentation, relocation, and dispersal necessitated close collaboration between the LWR industry and DOE-NE programs

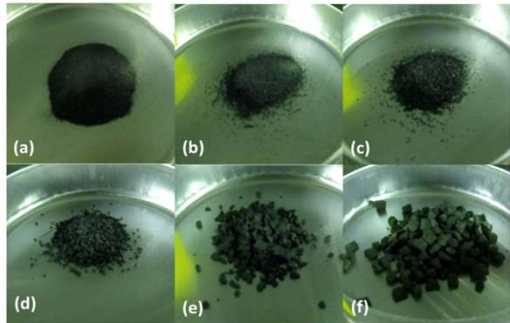
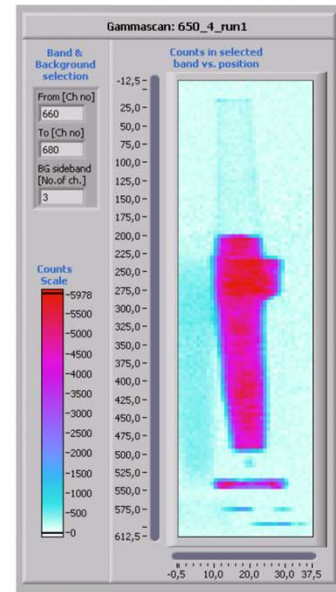
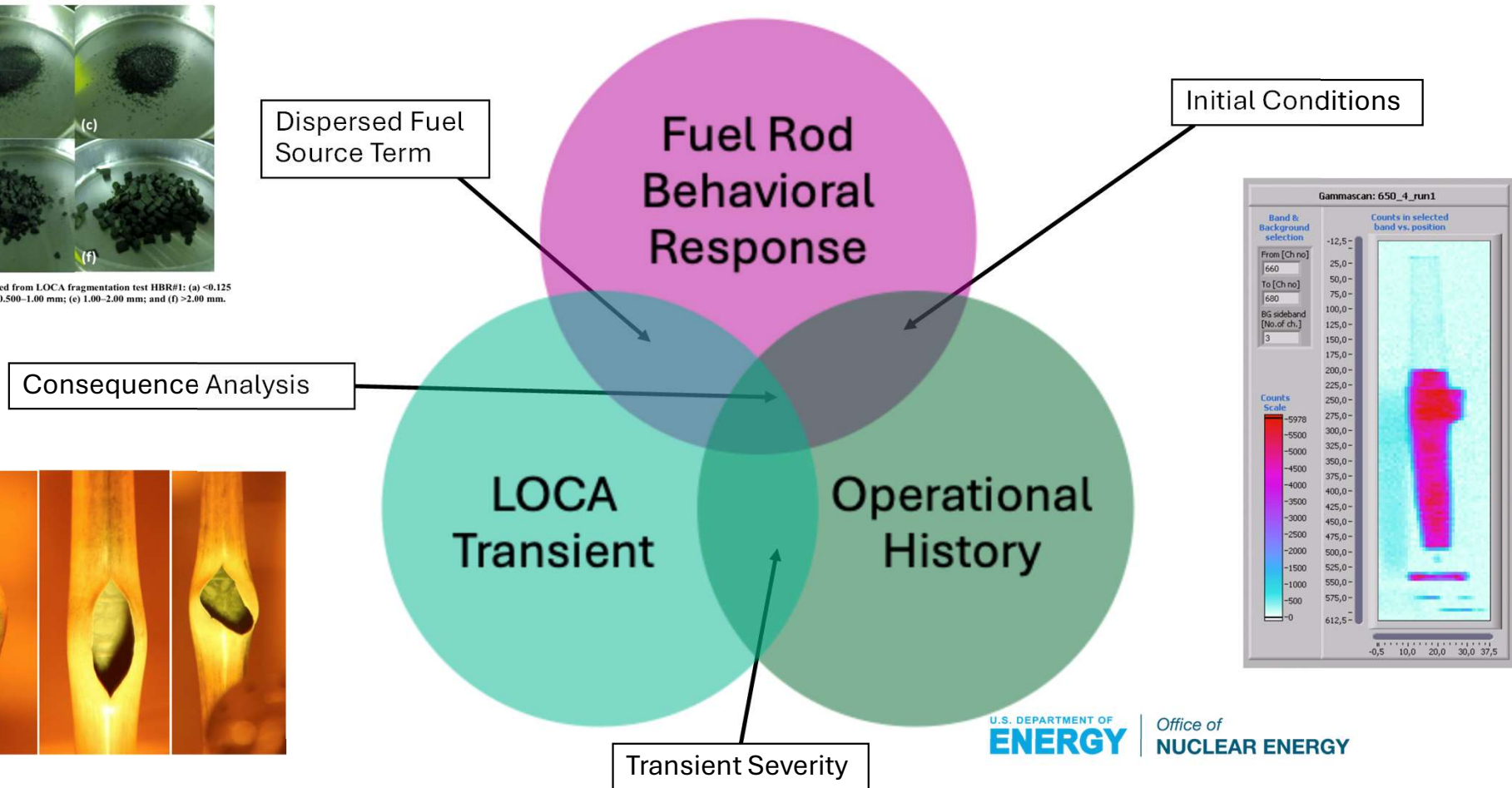


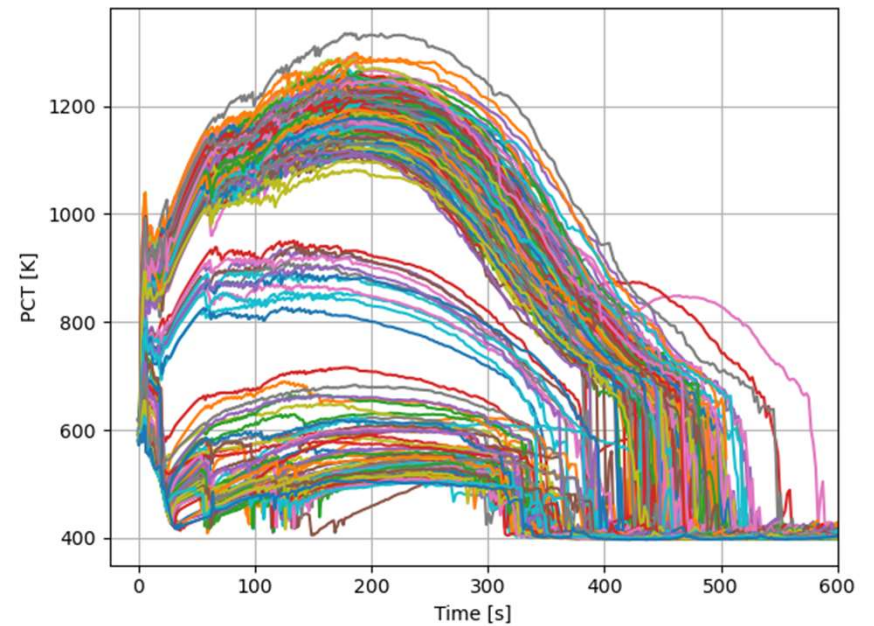
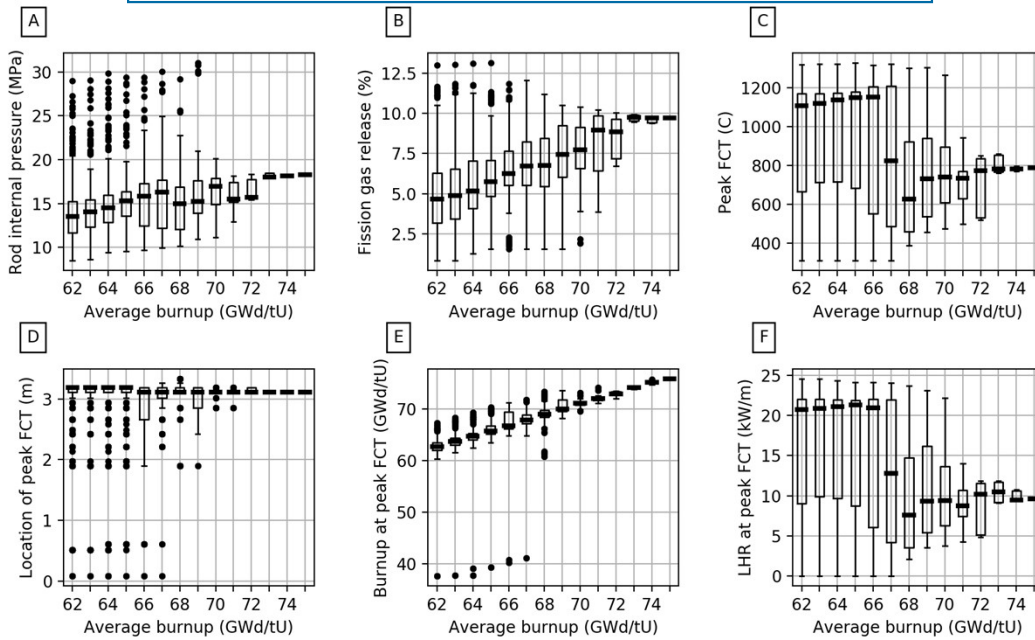
Figure 8. Images of fragmented fuel particles collected from LOCA fragmentation test HBR#1: (a) <math>0.125\text{ mm}</math>; (b)  $0.125\text{--}0.250\text{ mm}</math>; (c)  $0.250\text{--}0.500\text{ mm}</math>; (d)  $0.500\text{--}1.00\text{ mm}</math>; (e)  $1.00\text{--}2.00\text{ mm}</math>; and (f)  $>2.00\text{ mm}</math>.$$$$$



# NEAMS, in collaboration with Southern Nuclear Company and the EPRI CRAFT program, used advanced modeling and simulation tools to refine LOCA conditions for future testing

Steady State Core and Fuel Rod Performance

Transient Cladding Temperature Response



# The Advanced Fuels Campaign developed a consensus LOCA test plan and a set of targeted LOCA tests to address key data gaps and support the NRC's increased enrichment rulemaking

INLRPT-22-69915  
Revision 0

## Combined TREAT-LOC and SATS LOCA Experiment Plan

September 2022

*Integral LOCA Experiments on High-Burnup Fuels*

Colby Jensen, Robert Armstrong, Charles Folsom, Nicolas Woolstenhulme, David Kamerman, Fabiola Cappia, Daniel Wachs  
*Idaho National Laboratory*

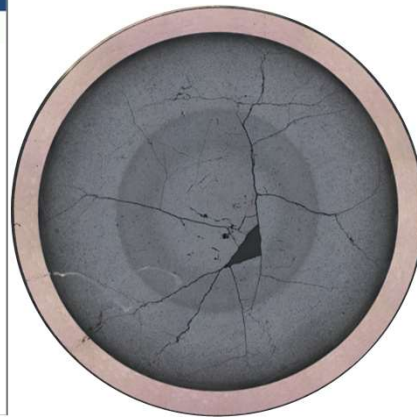
Nathan Capps, Jason Harp, Kory Linton  
*Oak Ridge National Laboratory*

**AFC** Advanced Fuels Campaign

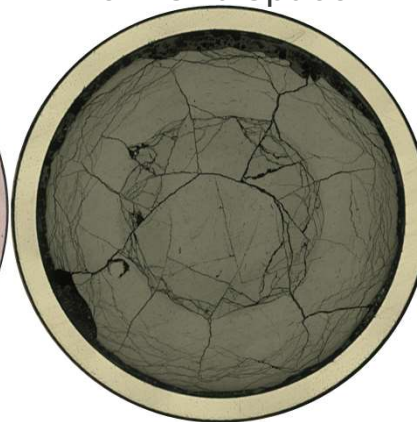
Simulated Grid Spacer



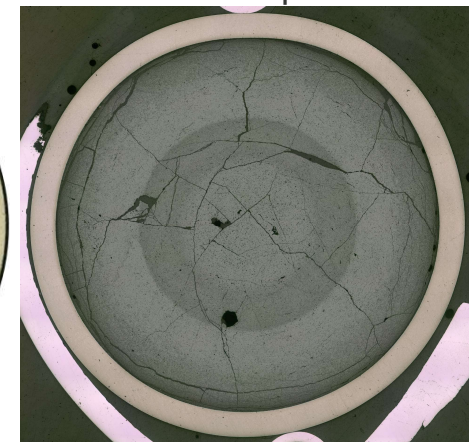
Pre-LOCA



Post LOCA away  
from Grid Spacer



Post LOCA away  
at Grid Spacer



# DOE-NE programmatic results and staff expertise have been leveraged by the staff to inform technical documents used to shape the future of LWRs and regulations



RIL 2021-13

## Interpretation of Research on Fuel Fragmentation, Relocation, and Dispersal at High Burnup

Date Published: December 2021

Prepared by:  
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### FFRD Impact on the Containment Source Term June 15 2021

Michael Salay, James Corson, Shawn Campbell

#### Abstract

The impact of fragmentation on the design-basis Containment Source Terms was evaluated. The considered source terms are that specified in RG1.183 Tables 1, 2, and 4 and a subsequent update to this source term for high-burnup fuel. This evaluation built upon considerable previous work on Severe Accidents, Source Term, and fuel fragmentation, relocation, and dispersal (FFRD) behavior during a loss-of-coolant accident, and on insights from the recent accident tolerant fuel (ATF) phenomena identification and ranking table (PIRT) exercise. Previous NRC documents regarding the impact of fragmentation focused on the recovered large break Loss-of-Coolant Accidents (LOCA)s involving functioning Emergency Core Cooling Systems (ECCS). Similar documents were not created to evaluate the impact of fragmentation on the Containment Source Term because of the expectation of a minimal impact. This document provides some of the reasoning behind this expectation and provides some simple scoping analyses supporting this expectation. The contribution of FFRD to the Containment Source Term is not significant, even when using unrealistically conservative assumptions regarding fuel fragment release magnitudes, transport behavior, concentration, and fragment heat up. When using more realistic assumptions for these effects, the source term with fragmentation is bounded by an equivalently developed Current Source Term without these effects. Two aspects of release in the Containment Source Term can be enhanced by fragmentation; enhanced early noble gas (NG) release upon clad burst, and earlier relocation of some of the decay heat carried by fragments to the lower head and the water remaining there. Both aspects affect the timing of radionuclide release to the containment. The magnitude of NG release from fragments cannot significantly increase the Containment Source Term NG release for high burnup because existing analyses already predict near-total NG release. Some NGs can release earlier because of high burnup. Given the expected fragment fraction and dispersal, it is considered unlikely that fuel collects in an unfavorable configuration, heats up, and releases large quantities of volatile radionuclides that would not otherwise have been released. The RG1.183 endorsed codes, ORIGEN, RADTRAD, and MELCOR, were briefly evaluated considering FFRD behavior. The codes are considered adequate for conservatively capturing FFRD behavior. Areas where calculations could be modified to better represent FFRD behavior were identified.

Research Information Letter  
Office of Nuclear Regulatory Research



NUREG/CR-7307

## Phenomena Identification and Ranking Tables on High Burnup Fuel Fragmentation, Relocation, Dispersal, and Its Consequences for Design-Basis Accidents in Pressurized- and Boiling-Water Reactors

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James Corson and Shawn Campbell, NRC Project Managers

Office of Nuclear Regulatory Research

## Increased Enrichment of Conventional and Accident Tolerant Fuel Designs for Light-Water Reactors

RIN Number: 3150-AK79

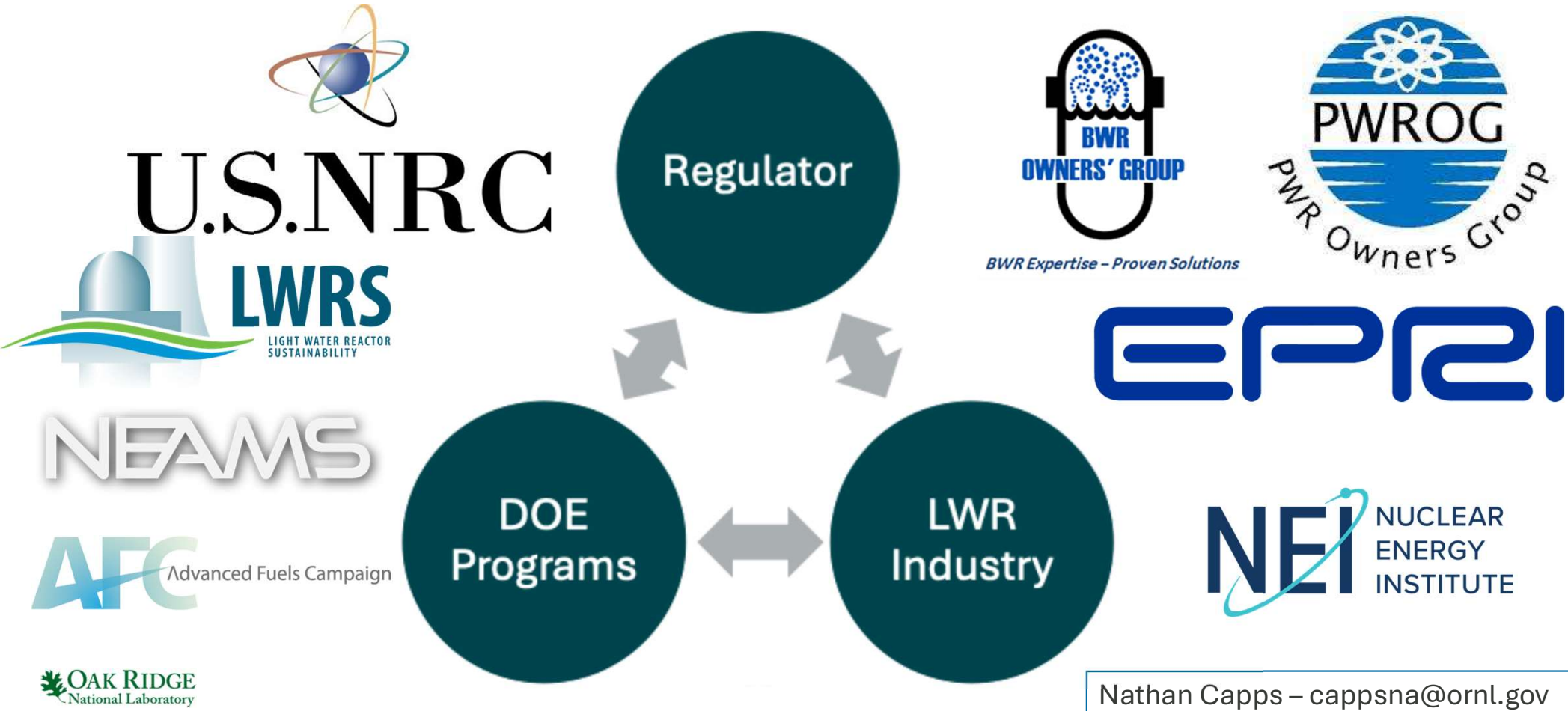
NRC Docket ID: NRC-2020-0034

### Regulatory Basis Document for Public Comment

September 2023



Enabling bold innovations to increase power generation across the nation's LWRs requires coordinated alignment between DOE resources and R&D, industry expertise, and targeted regulatory reforms



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