SAND2020-7174PE

IAEA CRP I31033 :

SNL YEAR 1 PROGRESS

Lucas I. Albright, KC Wagner, Jesse Phillips, David L. Luxat

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IUP Integrated University Program

U.S. Department of Energy

NUCLEAR ENGINEERING COLLEGE OF ENGINEERING | THE UNIVERSITY OF UTAH

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IAEA CRP I31033 "Advancing the State-of-Practice in Uncertainty and Sensitivity Methodologies for Severe Accident Analysis in Water Cooled Reactors"

Contents

Year 1 Progress Overview

Task	Comment	Status
Plant Model Development	–	Complete
Input Parameter Selection	–	Complete
PDF Selection	–	Complete
Methodology	• Not a "best-estimate" uncertainty analysis • We believe application of "best-estimate" uncertainty analysis methodologies to be misaligned with some project objectives • We apply modified uncertainty analysis methodologies that is consistent with project objectives – explained in the following slides	In progress
Reference Case	–	Complete
Summary Report	No delays expected	In progress

Project Objectives and Uncertainty Analysis Methodology

Investigate model form uncertainty between two material interaction modelling options available in MELCOR

Explore the range of MELCOR results produced by each respective model

Inform future MELCOR model development

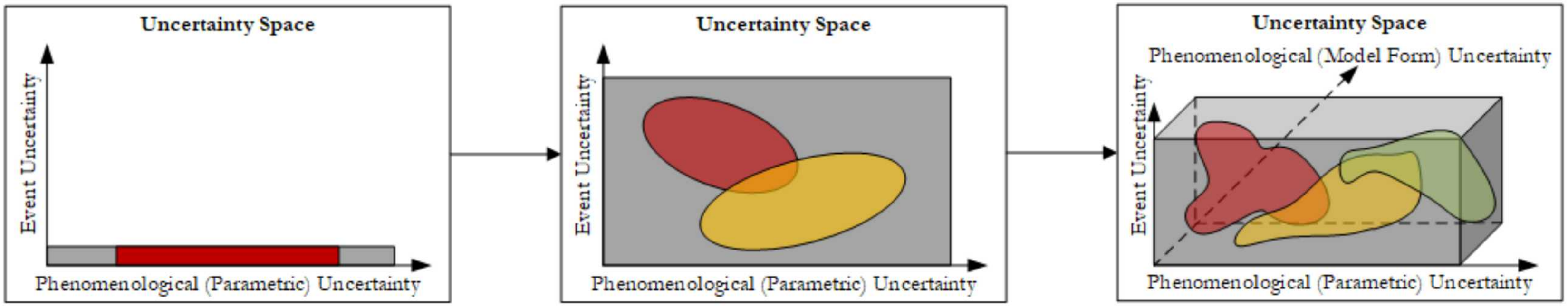
This UA is different from previous SNL studies which considered source term and consequence uncertainty (e.g., NUREG/CR-7155)

Research Objectives:

- Comparison of the overall accident progression exhibited by each model
- Comparison of the distributions of different figures of merit
- Identification of correlations and biases that each model may introduce

Expansion of the uncertainty space domain:

- Inclusion of other forms of uncertainty is a more "complete" representation of reality
- Gross bifurcations may emerge (due to model differences, modelling gaps, etc.)



Methodology

Not a "best-estimate" uncertainty analysis – not attempting to quantify the uncertainty in a traditional sense

Identify the underlying biases of each model through an "exploratory" uncertainty analysis

- Not using "best-estimate" distributions of input parameters or attempting to establish "best-estimate" distributions of FOMs
- Uniform distributions are utilized to promote coverage of the uncertainty space and perform a "blind" comparison of models
  - Removal of a priori biases on input and result distributions to investigate model form bias

Comparison

- Qualitative comparison of results (magnitudes, timings, and distribution/clustering characteristics)
- Quantitative comparison of results (minimums, maximums, etc.)
- Pointedly avoiding application of statistical methods that may impose misleading "artifacts" and inappropriate structure to the data

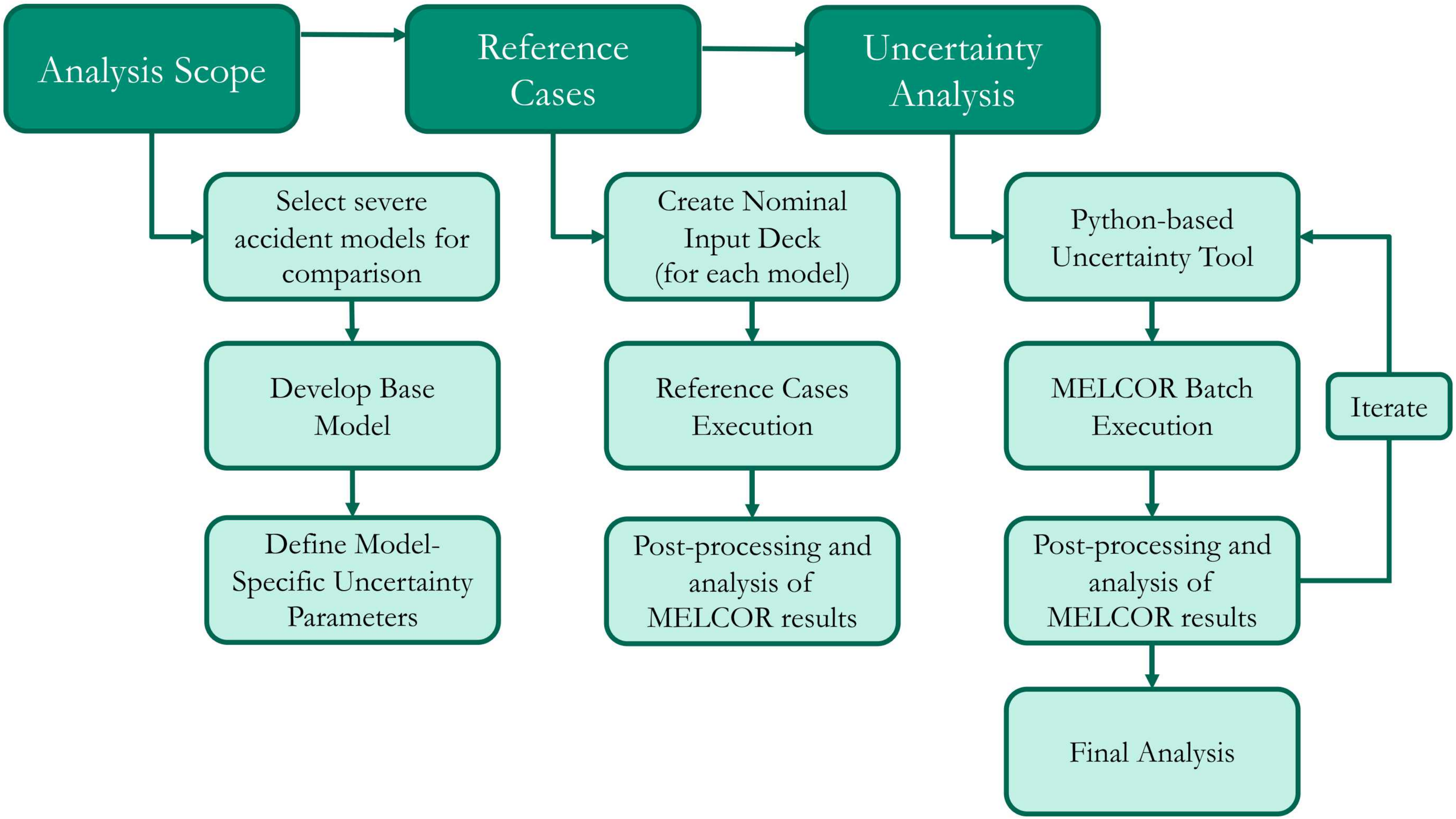
Correlation

- Identification of unknown correlations between input parameters and FOMs or multiple FOMs.
- Comparison of known/unknown correlations between each model

Clustering

- Identification of result clustering within each model's distribution
- Identification of cluster differences between models (cluster "existence", "location", and "size").

Uncertainty Analysis Workflow



Model Description

Plant Description

- 460 MW(e) BWR/3 reactor, Mk-I containment
- Core thermal hydraulic phenomena modeled in 26 control volumes (1 lower plenum, 25 core region)
- Core degradation phenomena modeled in 88 core cells (50 active core, 38 lower plenum)
- Containment phenomena modeled in 6 control volumes

Scenario Description

- Modelling assumptions and boundary conditions

Boundary Condition	Description
RPV Depressurization prior to Lower Head Failure	Not permitted
Lower Head Gross Creep Failure	Permitted
Lower Head Penetration Failure	Not permitted
Drywell Head Flange leakage	Begins at 0.6481 MPa pressure in the drywell
Main Steam Line Isolation Valve Closure	At 0.0 hours
Feedwater System Ceases Operation	At 0.0 hours
IC Train A Operation	0.1-0.28 hours 0.52-0.55 hours 0.63-0.67 hours 0.77-0.8 hours
IC Train B Operation	0.1-0.28 hours
Wetwell Venting	At 23.7 hours
Reactor Building Explosion	At 24.8 hours

Input Parameters

Input Record	Description	Units	Distribution	Parameter Options		Reference
				Interactive Materials Model	Eutectics Model	
Material Interaction Model						
Material Interaction Model Activation	This analysis involves a comparison of the interactive materials and eutectics models available in MELCOR	-	-	Interactive Materials Model Activate	Eutectics Model Activate	-
MP_PRC: ZRO2-INT, UO2-INT	Interactive materials model reduced liquefactions temperatures for ZRO2-INT and UO2-INT	K	Uniform	2230.0-2728.0	-	Informed by SOARCA (3σ)
Candling Models						
COR _SC: 1131(2)	Molten Material Holdup Parameters: Maximum ZrO2 temperature permitted to hold up molten Zr in CL.	K	Uniform	2100-2540	2100-2540	Informed by SOARCA (min-max)
COR _SC: 1141(2)	Core Melt Breakthrough Candling Parameters: Maximum melt flow rate per unit width after breakthrough	kg m/s	Uniform	0.1-2.0	0.1-2.0	Informed by SOARCA (min-max)
Fuel Rod Failure Models						
COR_ROD	Rod Collapse Model	-	Discrete Uniform	Active (0), Disabled (1)	Active (0), Disabled (1)	-
COR_CCT: DRZRMN	Component Critical Minimum Thicknesses	m	Uniform	0.0-0.00015	0.0-0.00015	
COR_SC: 1132(1)	Core Component Failure Parameters: Temperature to which oxidized fuel rods can stand in the absence of unoxidized Zr in the cladding.	K	Uniform	2230.0-2728.0	2230.0-2728.0	Informed by SOARCA (3σ)
Debris Quenching and Dryout Models						
COR_EDR: DHYPD, DHYPB (Active Core)	Particulate debris equivalent diameter in the active core region	m	Uniform	0.005-0.015	0.005-0.015	Engineering judgement
COR_EDR: DHYPD, DHYPB (Lower Plenum)	Particulate debris equivalent diameter in the lower plenum	m	Uniform	0.0001-0.005	0.0001-0.005	Engineering judgement
COR_LP: HDBH2O	Heat transfer coefficient of falling debris	W/m^2K	Uniform	100.0-4000.0	100.0-4000.0	Engineering judgement
COR_LP: VFALL	Velocity of falling debris	m/s	Correlated to particulate debris diameter in the lower plenum	-	-	Engineering judgement
COR _SC: 1244 (3)	Debris Dryout Heat Flux Correlation: Minimum Debris Porosity	-	Uniform	0.15-0.4	0.15-0.4	Engineering judgement
COR_TST: IMPLZDM	Lipinski zero-dimensional dryout heat flux flag	-	Discrete Uniform	Active (0), Disabled (1)	Active (0), Disabled (1)	-
Numerical Uncertainty						
CVH_SC: 4422 (2)	A random number seed that varies the t/h solution matrix to include and evaluate numerical model variance importance . A value of 0.0 indicates that MELCOR will generate a random number seed based on the system clock time.	-	Uniform	1-1e6	1-1e6	-

Reference Case

Transient: Short term station blackout (STSBO)

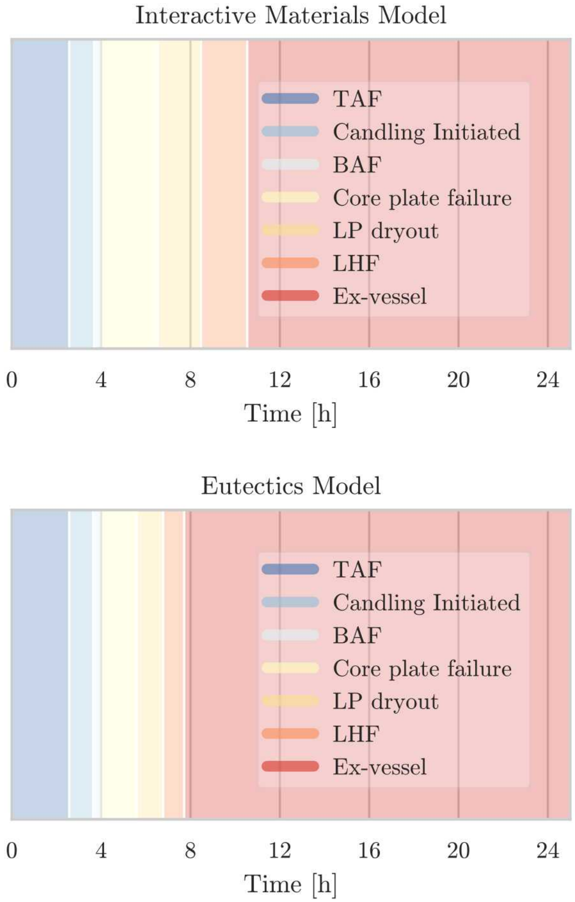
Simulation length: 25 hours

Key outputs for FOM Determination

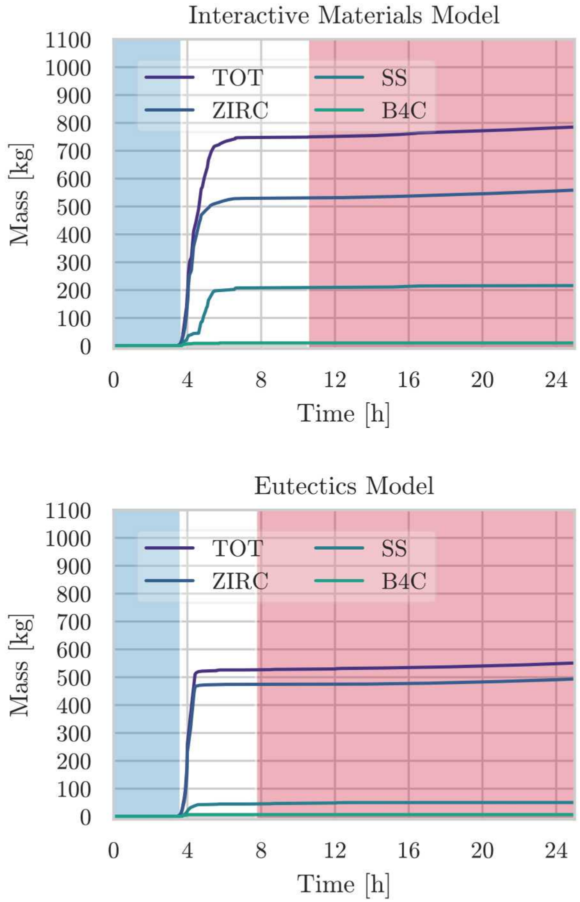
- Overall Accident Progression
  - Key event timings
- Hydrogen Generation
- Thermal Hydraulic Response
  - Primary Coolant System Response
  - Containment Response
- Reactor Core Degradation
- RPV Lower Head Breach

Input Record	Reference Case Parameter Values	
	Interactive Materials Model	Eutectics Model
Material Interaction Model		
Material Interaction Model Activation	Interactive Materials Model	Eutectics Model
MP_PRC: ZRO2-INT, UO2-INT	2479.0	–
Candling Models		
COR _SC: 1131(2)	2400.0	2400.0
COR _SC: 1141(2)	1.0	1.0
Fuel Rod Failure Models		
COR_ROD	Active (0)	Active (0)
COR_CCT: DRZRMN	0.0001	0.0001
COR_SC: 1132(1)	2479.0	2479.0
Debris Quenching and Dryout Models		
COR_EDR: DHYPD, DHYPB (Active Core)	0.01	0.01
COR_EDR: DHYPD, DHYPB (Lower Plenum)	0.002	0.002
COR_LP: HDBH2O	4000.0	4000.0
COR_LP: VFALL	1.5	1.5
COR _SC: 1244 (3)	0.15	0.15
COR_TST: IMPLZDM	Active (0)	Active (0)
Numerical Uncertainty		
CVH_SC: 4422 (2)	492074	492074

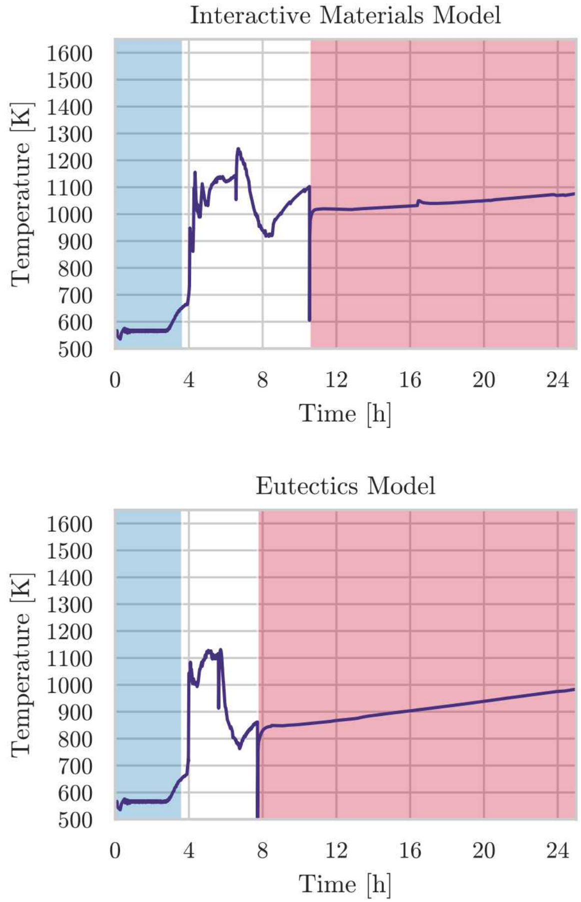
Sample Results



Accident Progression

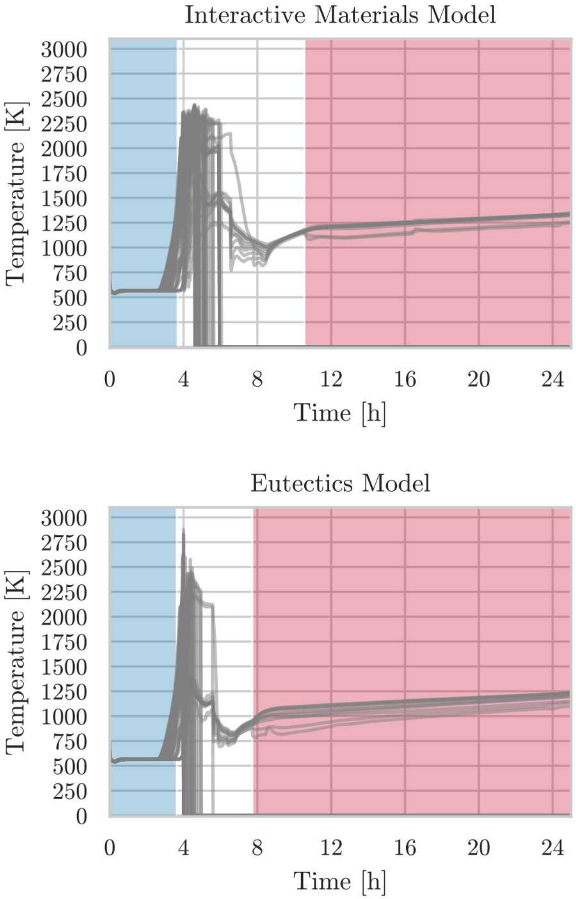


Hydrogen Generation

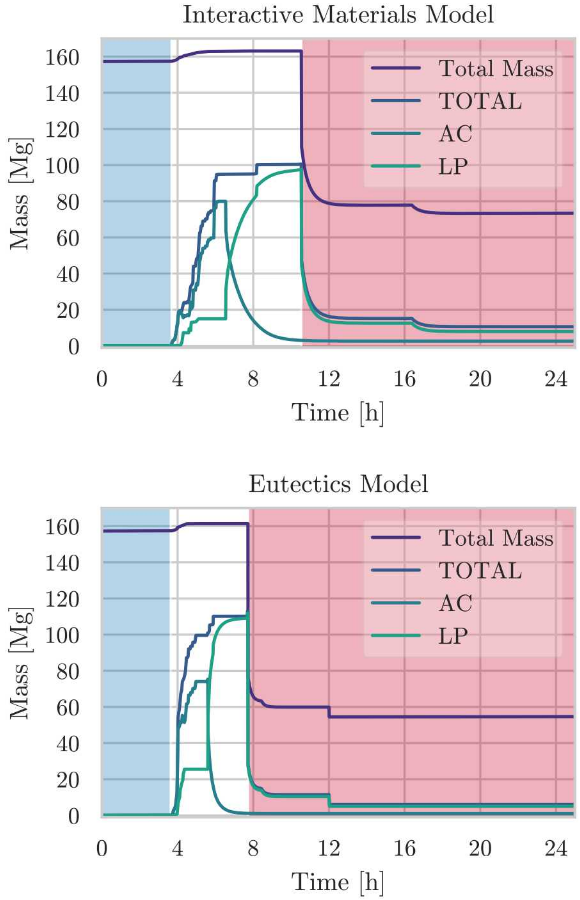


Steamdome Temperature

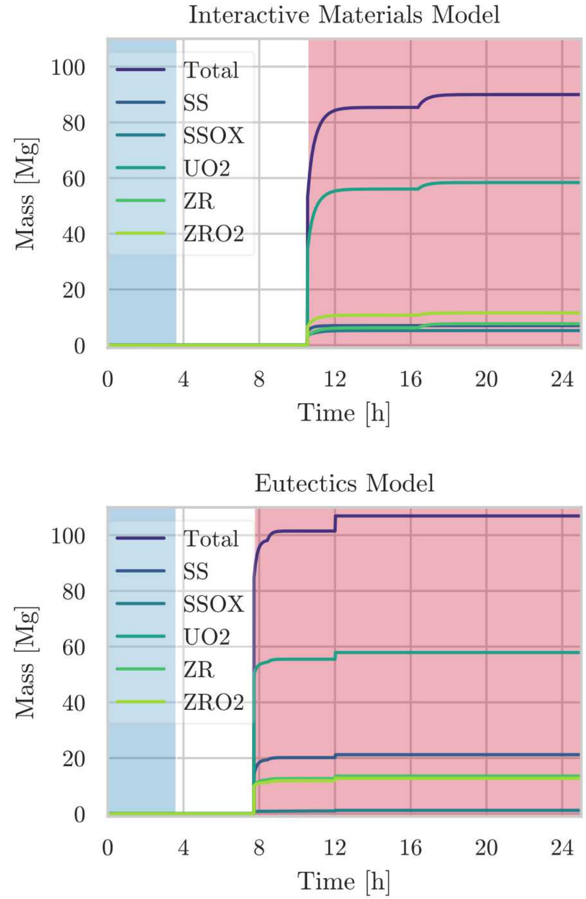
Sample Results



Fuel Temperature



Debris Distribution



Ejected Mass

Acknowledgements

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