SAND2017-9864PE

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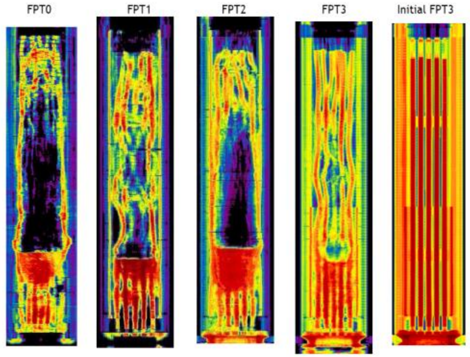
Source: Tokyo Electric Power Company



Update on Code Crosswalk Activities

NRC - SNL – EPRI – IAE – IRSN

Presented by Nathan Andrews

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

NNSA National Nuclear Security Administration

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MELCOR Crosswalk Analyses

- Objectives
  - Inform modelers and experimenters as to key phenomenological uncertainties
  - Better explain how uncertainties and modeling different drive accident scenarios
- History
  - Originally EPRI/SNL/DOE/NRC collaboration, has since expanded
- Timeframe
  - Phase I: 2014-2017
  - Phase II: 2016-present
- Scenarios
  - Phase I: Unmitigated 1F1 accident, with SRV seizure at 7.0 hours
  - Phase II: Recovered 1F1 accident, with SRV seizure at 3.0 hours
- Cooperative Agreements
  - DOE LWRS
  - CSARP
  - Civil Nuclear Working Group (CNWG)

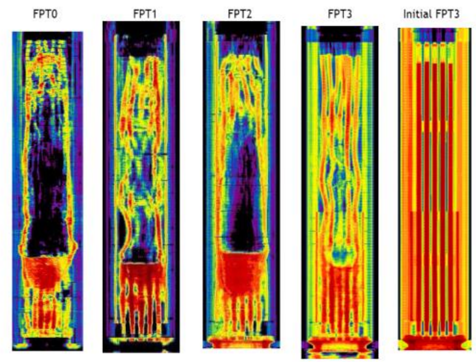
Crosswalk Methodology

- As similar as possible input parameters across all programs
  - Initial masses – water, core structures, fuel
  - Geometry
- Near-identical boundary conditions
  - Operating reactor systems
  - Decay heat
  - Depressurization
- Phenomenological assumptions
  - Best estimate models for each code
  - Ensure that the analysis reflects how a “typical user” would use the different codes

Current Crosswalk Activities

- MELCOR-SAMPSON Crosswalk Phase I
  - Preliminary calculations performed by IAE
    - Conclusions shown are those from an IAE-only analysis
  - Was presented at NURETH-17
  - Joint paper will be written in early FY18
- MELCOR-ASTEC Crosswalk Phase I
  - Analysis completed and presented at:
    - MCAP (2016), ERMSAR (2017), NURETH (2017)
  - Completed conversion to newest NUREG format
- MAAP-MELCOR Crosswalk Phase II
  - Scenario set up and code cases completed
  - Recovered accident analysis
    - Varying injection timing and amount
  - Report expected to be published by the end of October
  - Incorporate both ASTEC and SAMPSON next FY

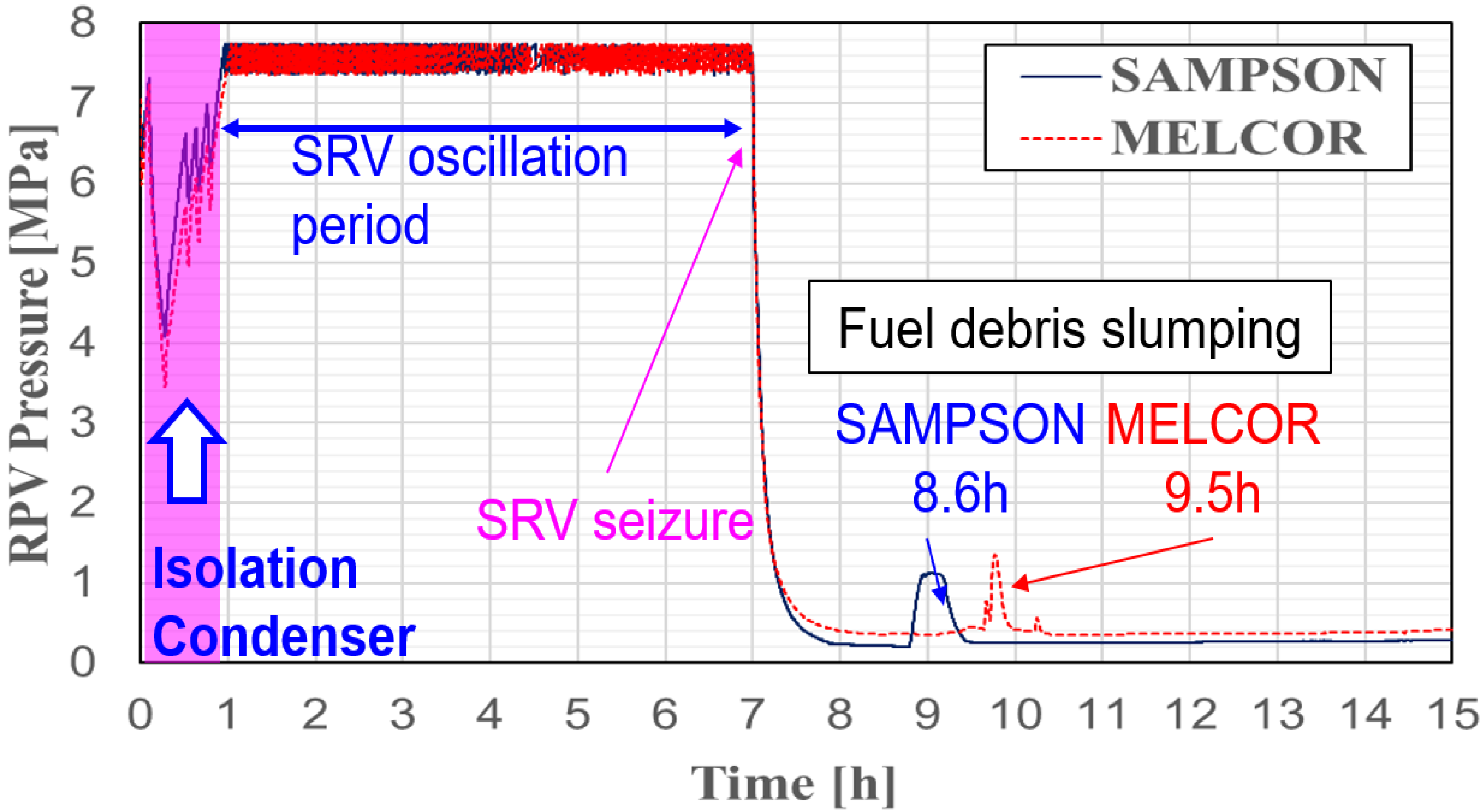
Source: Tokyo Electric Power Company



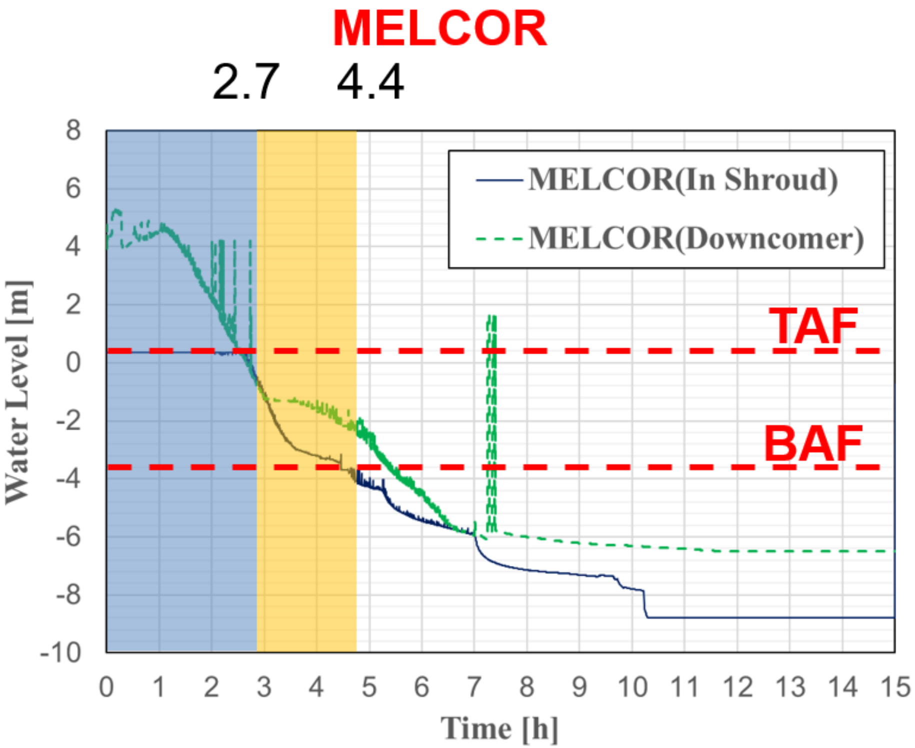
CROSSWALK ANALYSIS

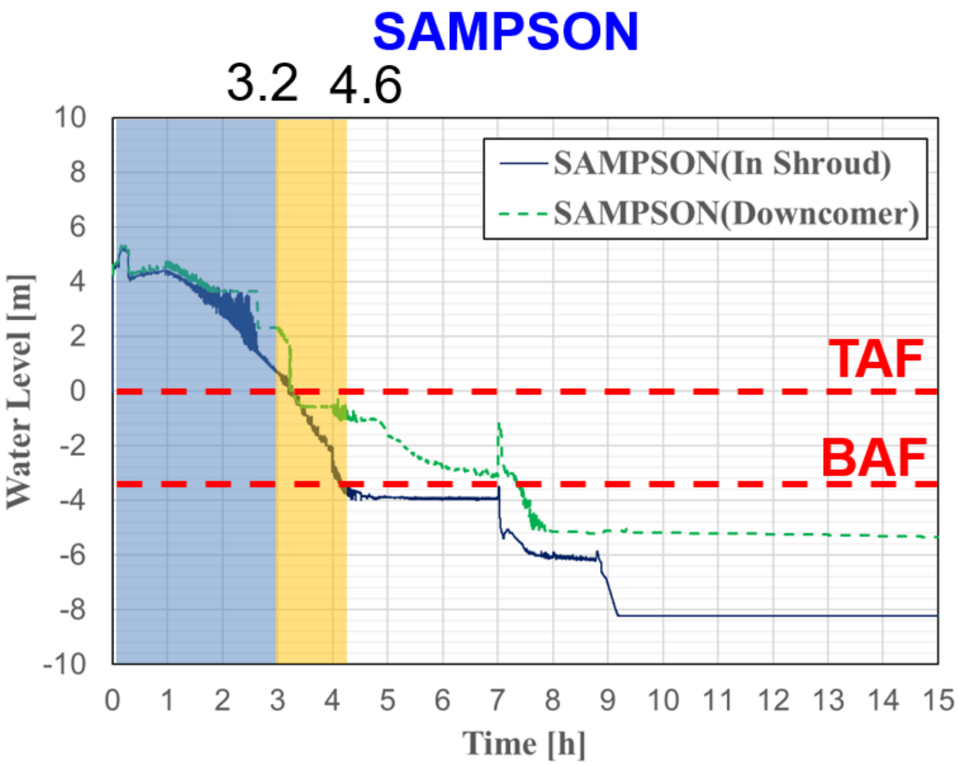
PHASE I - CODE COMPARISONS

MELCOR-SAMPSON Crosswalk, IAE Conclusions



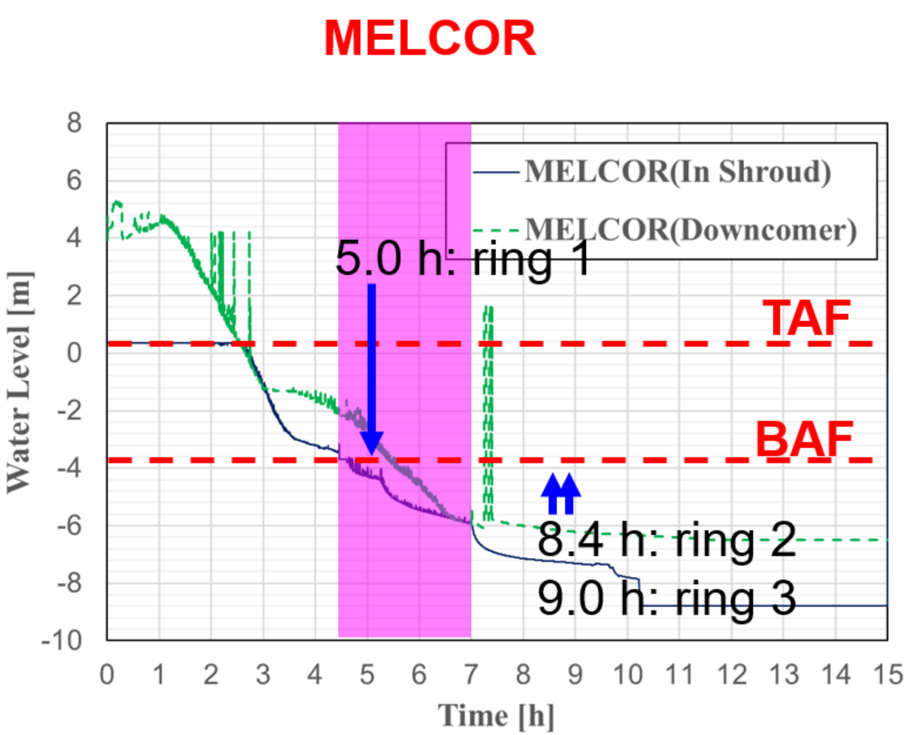
MELCOR-SAMPSON Crosswalk, IAE Conclusions

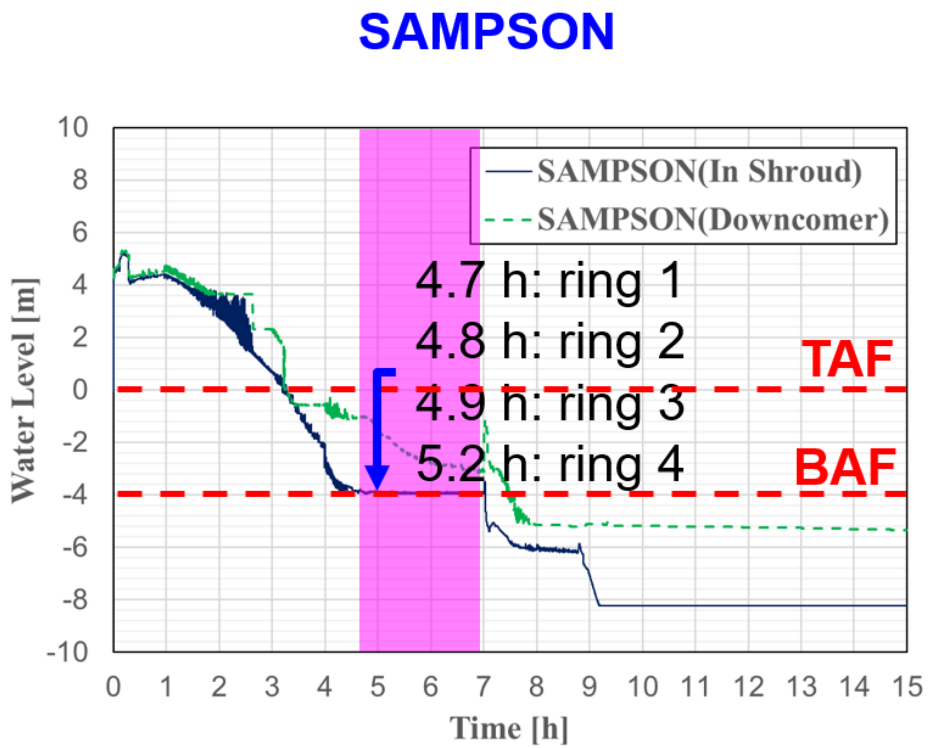




- The two codes respond very similarly until the core uncover phase with differences within 30 minutes
- Differences exist in the subsequent phase of the core degradation

MELCOR-SAMPSON Crosswalk, IAE Conclusions

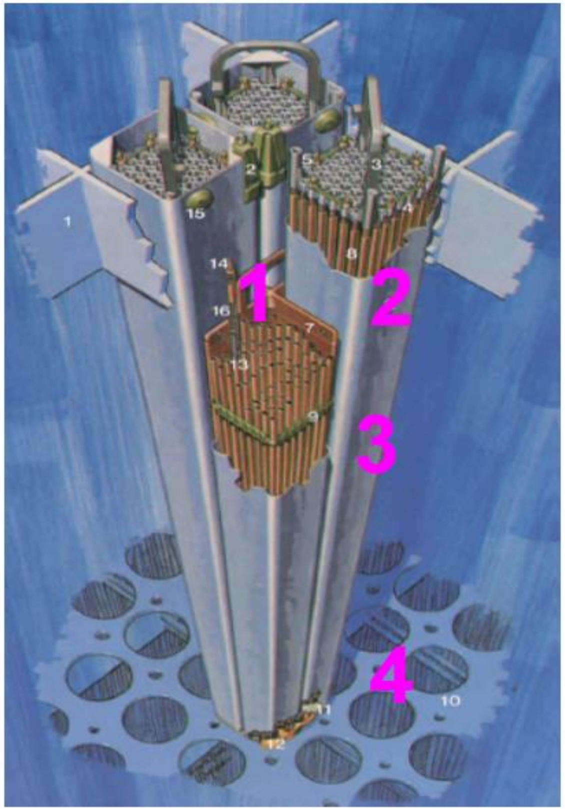




- **Two main differences:**

1. SAMPSON computes faster degradation of the fuel compared to MELCOR
2. SAMPSON computes almost constant water level below BAF

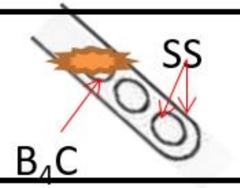
MELCOR/SAMPSON Component Failure Models



1. Control Blade

[MELCOR] B_4C-SS formation 1520 K

[SAMPSON] B_4C-SS formation 1500 K



2. Control Blade ←→ Fuel Canister

[MELCOR] No model

[SAMPSON] B_4C-SS-Zr formation at 1500 K

3. Fuel-Cladding Melting and Relocation

[MELCOR] ZrO_2 layer thickness criteria

[SAMPSON] U-Zr-O formation and relocation at 2473 K

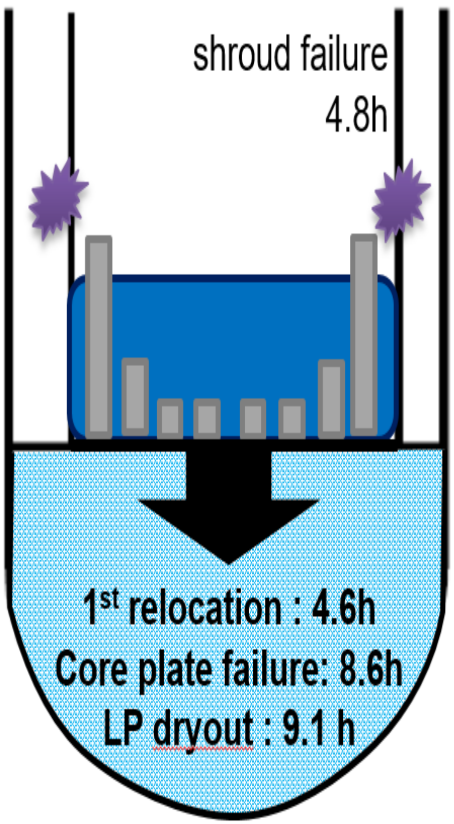
4. Fuel Assembly Collapse

[MELCOR] Fuel assembly collapse into a rubble bed of primarily fuel pins. Time-at-temperature approach is taken.

[SAMPSON] No model

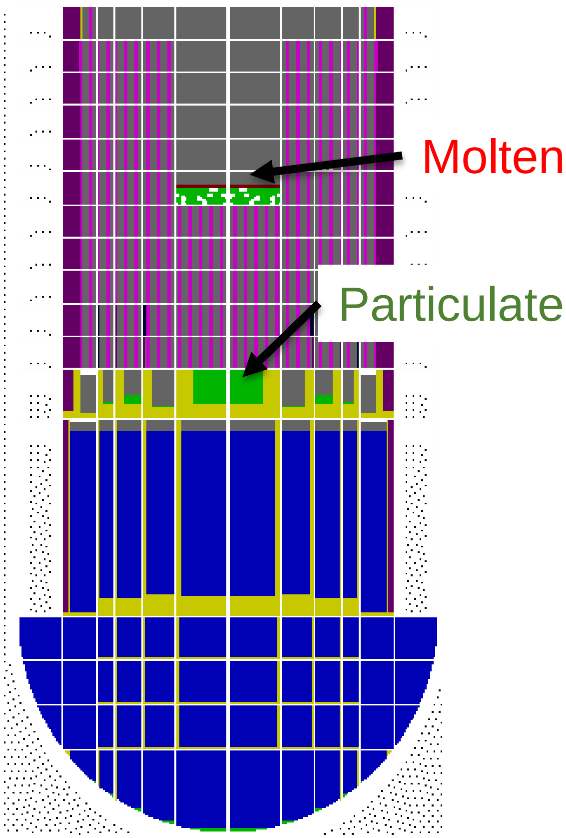
Phase I Crosswalk Comparison

SAMPSON



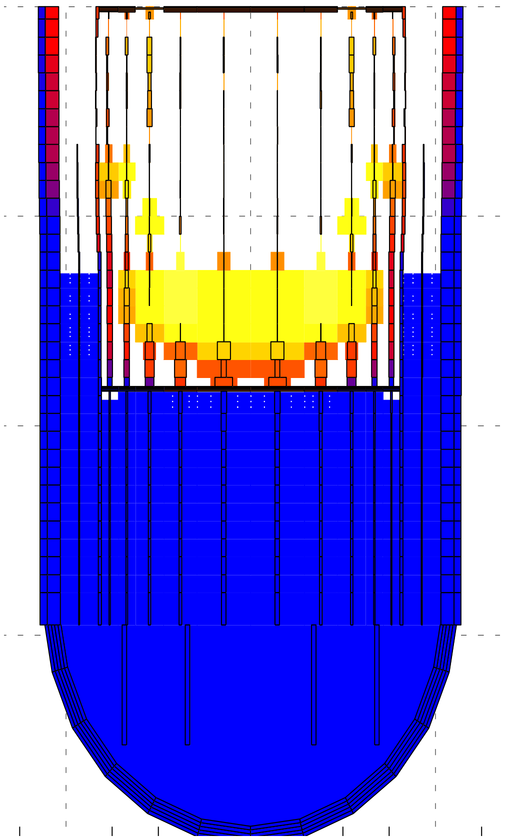
-Only particulate formed in-vessel

MELCOR



-Particulate & molten debris formed, molten is quenched then becomes particulate

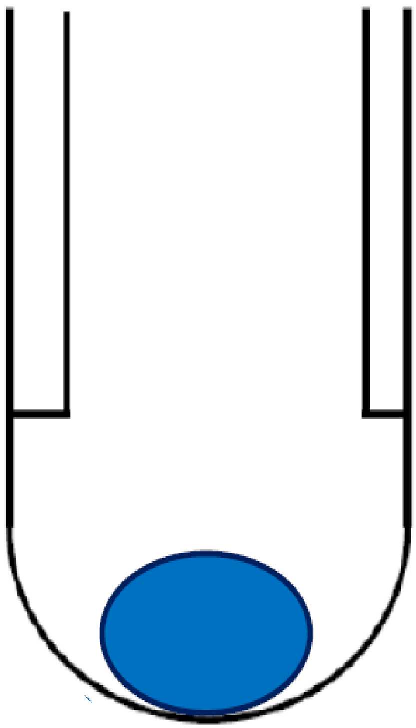
ASTEC & MAAP



-Crucible formed in the core region

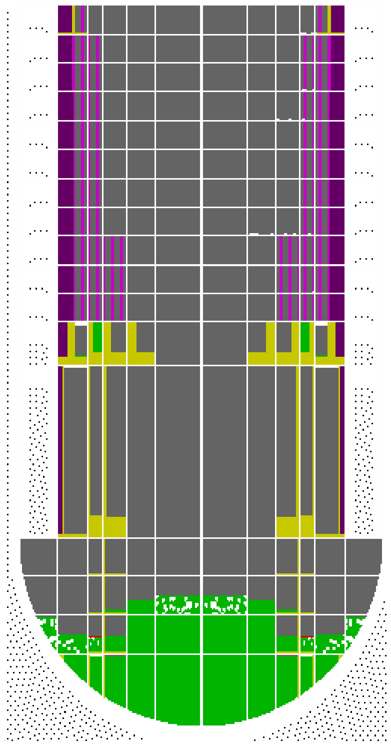
Phase I Crosswalk Comparison

SAMPSON



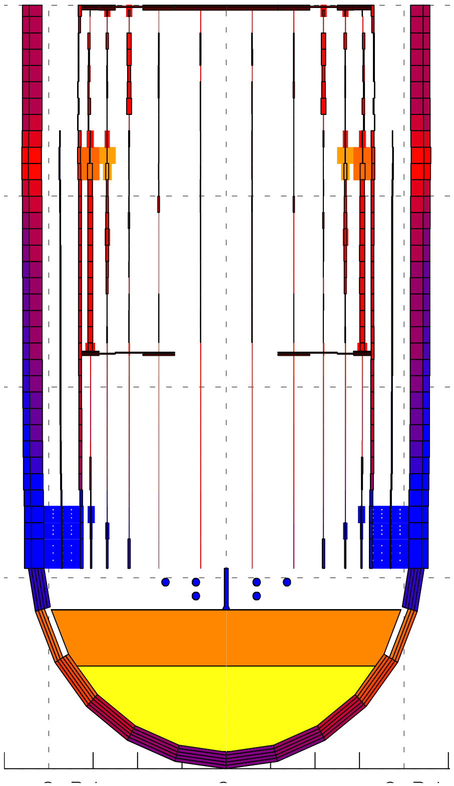
-Minimal fuel mass intact
-Particulate only in LP
-No RPV failure

MELCOR



-Significant fuel mass intact
-Particulate only in LP
-RPV Failure at 14.6 hours

ASTEC & MAAP



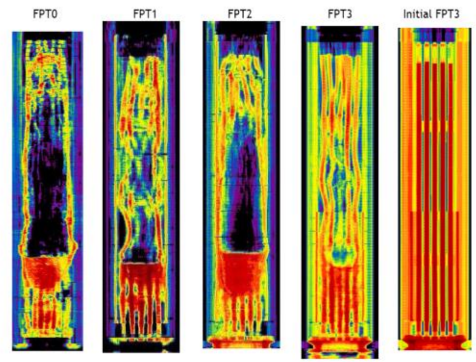
-Minimal fuel mass intact
-Molten pools in LP
-RPV Failure at 12.6 (MAAP), 15.6 hours (ASTEC)

Comparison of Particulate Debris Formation in Crosswalk Phase I

SAMPSON	MELCOR (v2.1)	ASTEC (v2.0)	MAAP (v5.03)
• Particulate Debris Only • 330 kg H_2	• Primarily Particulate Debris • 822 kg H_2	• Both Particulate and Molten Combined in “MAGMA” • 776 kg	• Molten Debris Only • 220 kg

- Spectrum of the amount of particulate and molten debris calculated in stylized 1F1 scenario
- MELCOR and ASTEC have much more hydrogen generation
  - May be due to higher steam flow through the reactor core region during the degradation process
  - Shroud fails in both SAMPSON and MAAP

Source: Tokyo Electric Power Company



MAAP5.04-MELCOR2.2 CROSSWALK

PHASE 2 – IMPACT OF CODE MODELING ON MITIGATED SEVERE ACCIDENT SCENARIOS

MAAP-MELCOR Crosswalk Phase II: Scenario Description

System	Behavior
Main Steam Line Isolation Valve (MSIV)	MSIV closure signal at 52.5 s after SCRAM
	MSIV open area reducing from fully open to fully closed over a 3 s interval from the time of the closure signal
Control Rod Drive (CRD)	At reactor scram it is assumed that the CRD injection flow ceases
Feedwater System	The feedwater system is assumed to inject for the first 60 s following the initiating event
	The feedwater injection transient is an imposed boundary condition
	The specific enthalpy of feedwater is assumed to be 792 kJ/kg
Safety Relief Valve (SRV)	SRV seizure is assumed to occur at 3 hours after SCRAM
	All discharge through the seized SRV is assumed to go into the suppression pool
Isolation Condenser (IC)	IC heat removal is assumed to be constant with pressure at 42.4 MW per train
	Three separate periods over the first hour
Water Injection into Downcomer	Varying timing and amounts

Phase II – Case Matrix

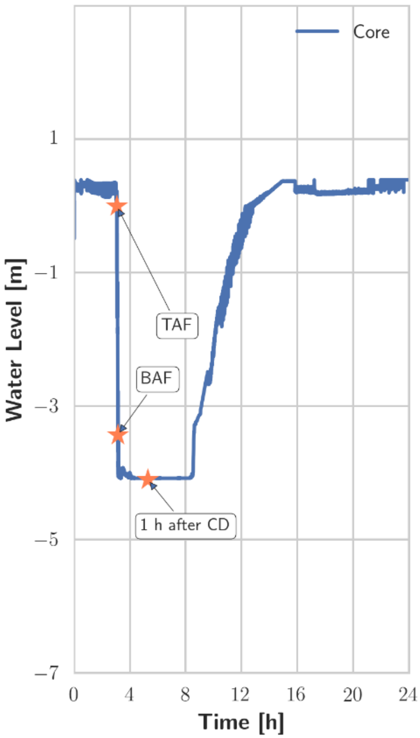
Case	Injection Rate (kg/s)	Injection Delay (hr)
1	5.0	0.00
2	5.0	0.25
3	5.0	1.0
4	5.0	2.0
5	5.0	3.0
6	5.0	5.0
7	0.0	1.0
8	1.0	1.0
9	2.5	1.0
10	5.0	1.0
11	15.0	1.0
12	20.0	1.0

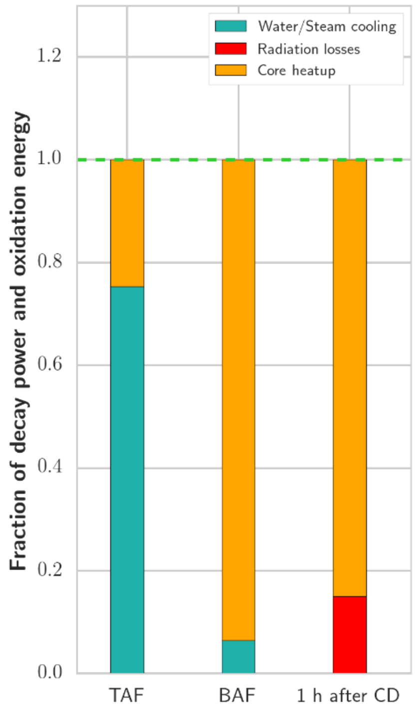
Reference Case

- Two separate sensitivity studies
  - Injection rates → at 1 hr from H_2 generation
  - Injection timings → 5 kg/s nominal value
- Update from MELCOR 2.1 to MELCOR 2.2
- Update from MAAP 5.03 to MAAP 5.04

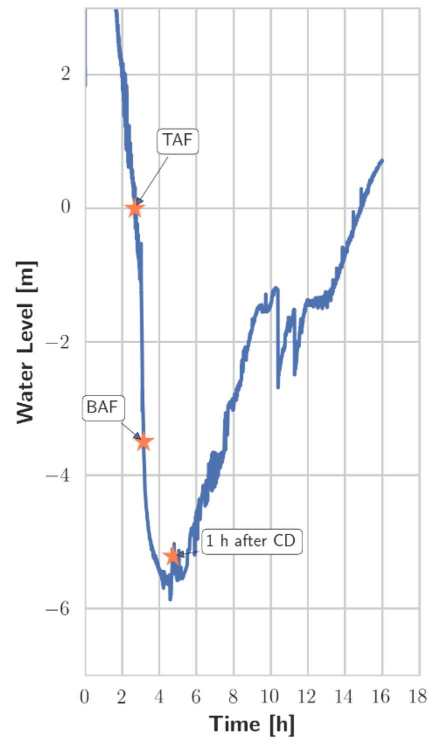
Effectiveness of Water Cooling, Collapsed Water Level

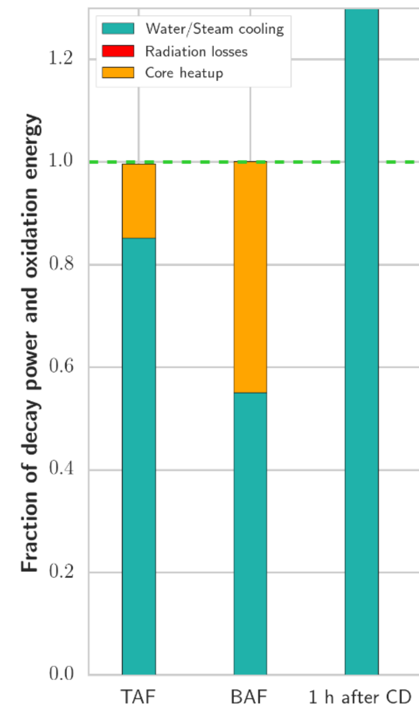
MAAP5





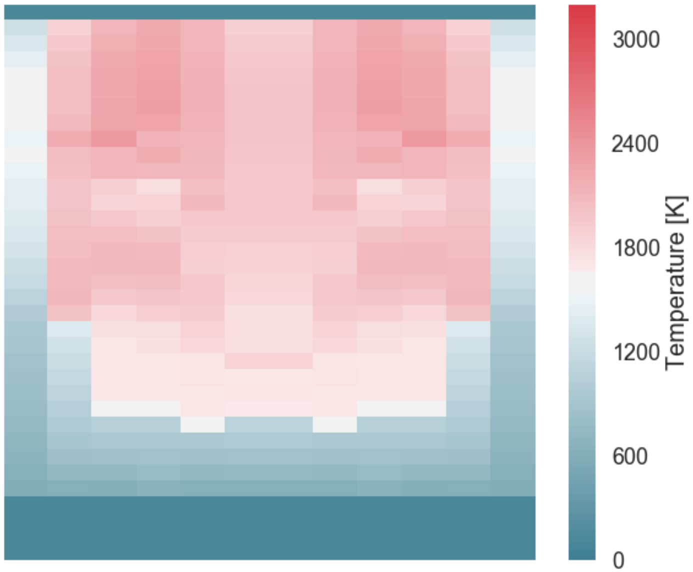
MELCOR





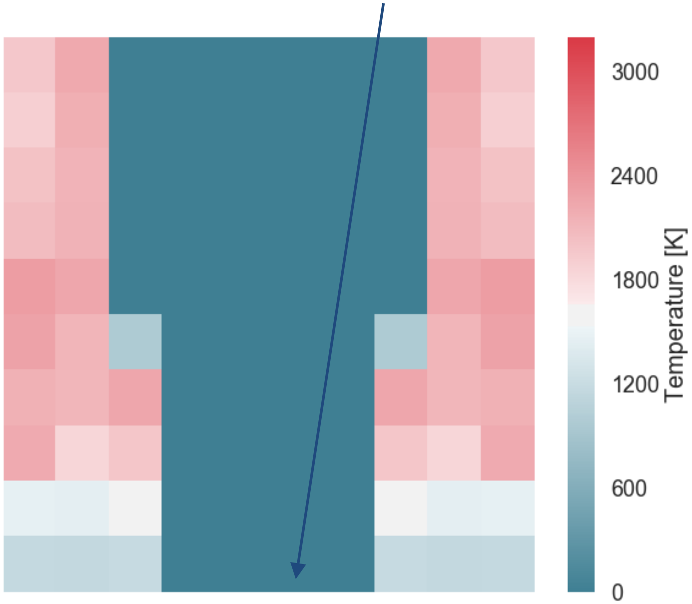
Peak Fuel Temperatures prior to Water Injection

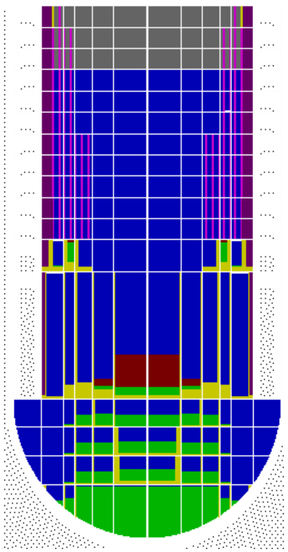
MAAP5 (5.9 hours)



MELCOR (4.8 hours)

Loss of core plate integrity in rings 1 and 2

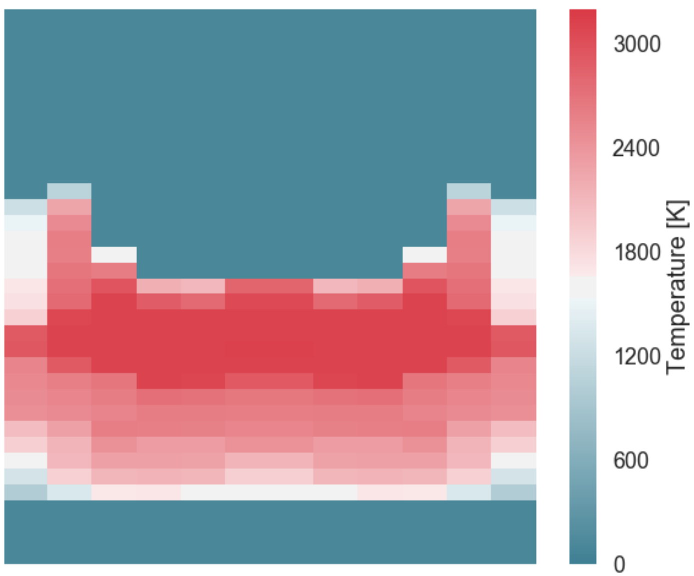




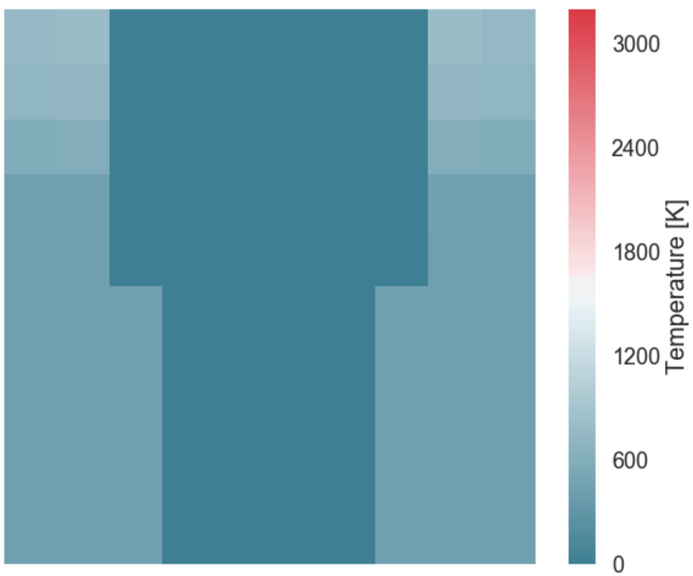
17420 (sec)

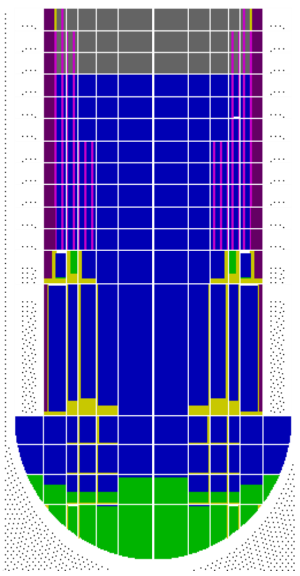
Long-Term Fuel Temperatures, 5.0 Hours after Water Injection Starts

MAAP5 (10.9 hours)



MELCOR (9.8 hours)





35400 (sec)

Key Outcomes

- Large uncertainties still exist in severe accident knowledge base for complex reactor-scale core melt progression
  - Highlights need for a large-scale experiment for BWR degradation
  - Proposed Argonne experiment?
- Factors of significant importance vary depending on phenomenological assumptions
  - Hydrogen production
  - Lower head failure timing
  - Long term coolability and recoverability
  - Containment water addition and management
- Comparison of models can lead to better training cases for operators and response personnel
  - Ensure operators are training for all possible scenarios