Idaho National Engineering and Environmental Laboratory

SCDAP/RELAP5-3D and Related INEEL Capabilities

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Objective

To discuss SCDAP/RELAP5-3D and introduce other related INEEL capabilities

Outline

- *SCDAP/RELAP5-3D*
  - *Capabilities*
  - *Comparisons with MELCOR*
  - *New features*
  - *Planned / proposed improvements*
- *Other related INEEL capabilities*
- *Summary*

SCDAP/RELAP5-3D Design Facilitates Reactor Assessments

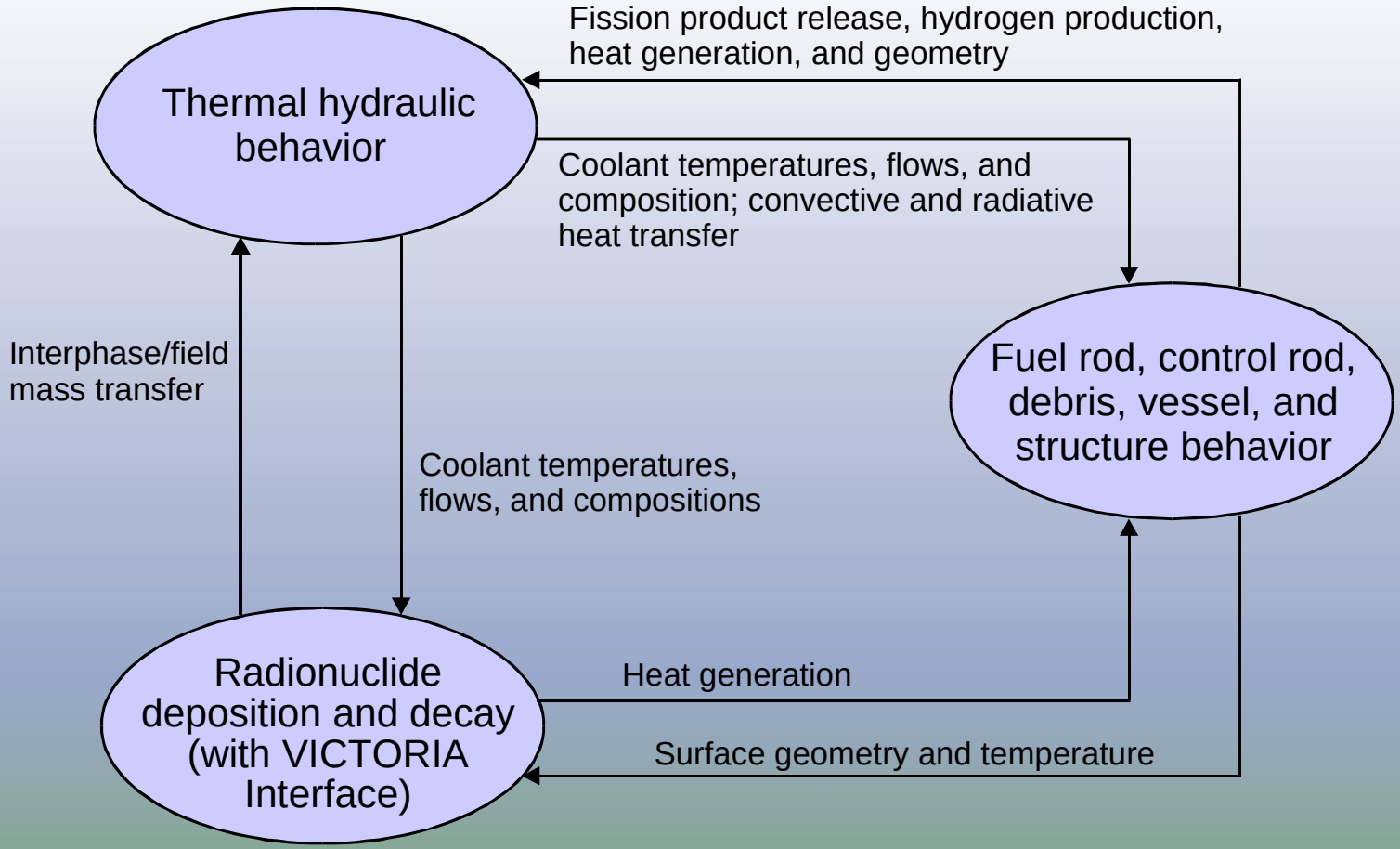
- *Building block approach for system thermal hydraulics*
- *Control system/trip logic*
- *Representative 2D fuel rods, control rods/blades, and structures for assessing early phases of melt progression*
- *Lumped parameter and 2D finite element models for modeling late phase behavior of debris and structures*
  - *In-core formation, growth, and collapse of molten pools, debris/melt/structural interactions treated with detailed, lumped parameter models*
  - *Relocation of molten core materials and upper plenum structures into lower head including interaction with (and degradation of) lower core support structures*
  - *Formation/growth of lower head molten pool (natural circulation treated with effective conductivity approach in 2D FE model)*

SCDAP/RELAP5-3D User Parameters Intentionally Minimized

- *TH nodalization and selection of representative core components*
- *TH models automatically select from 11 flow regimes*
- *Damage progression parameters limited to critical areas with significant modeling uncertainty*
  - *Defaults provided for user applications*
  - *Defaults set to best estimate values obtained from code-to-data comparisons*

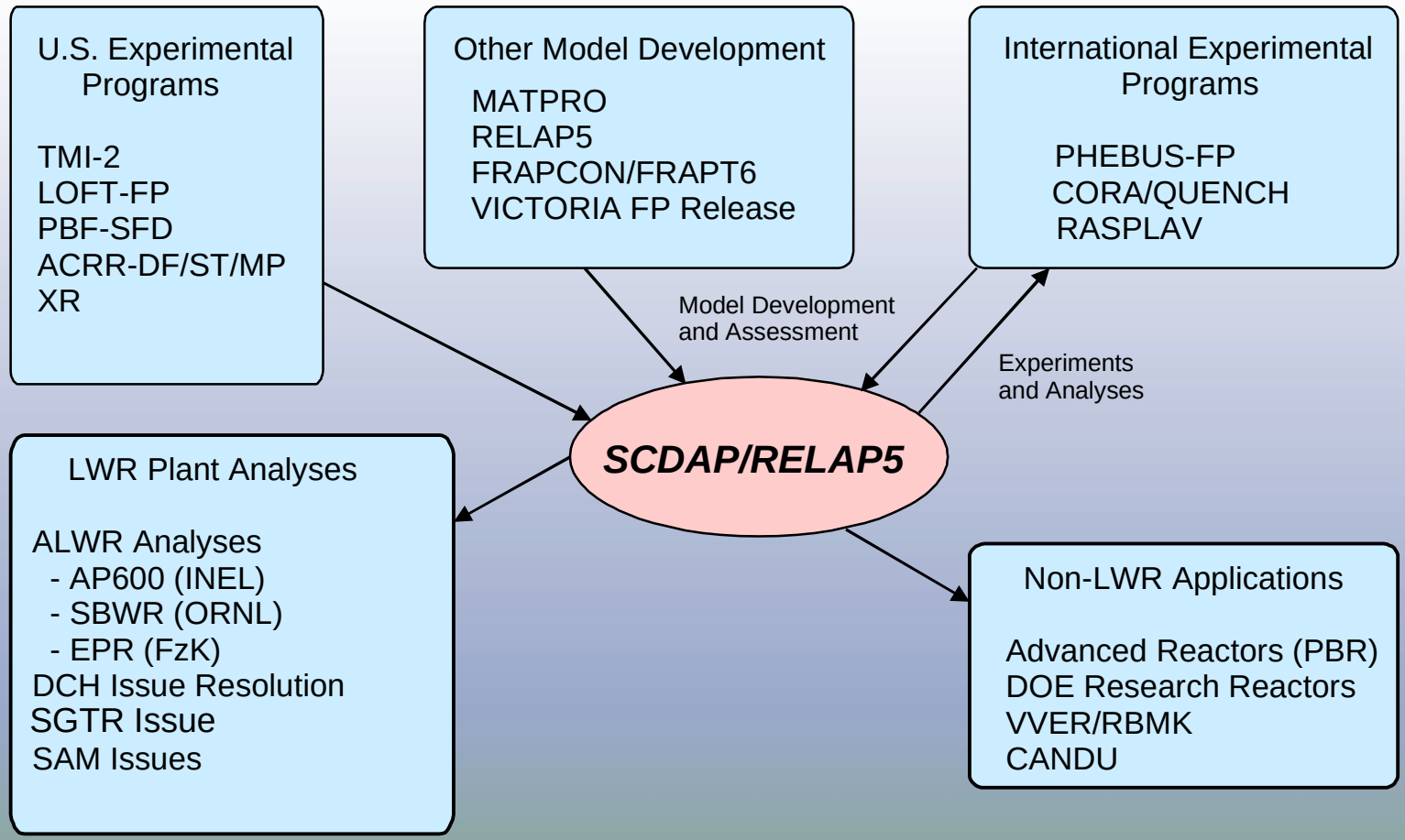
S/R5-3D Capabilities

SCDAP/RELAP5-3D Models Wide Range of Accident Phenomena



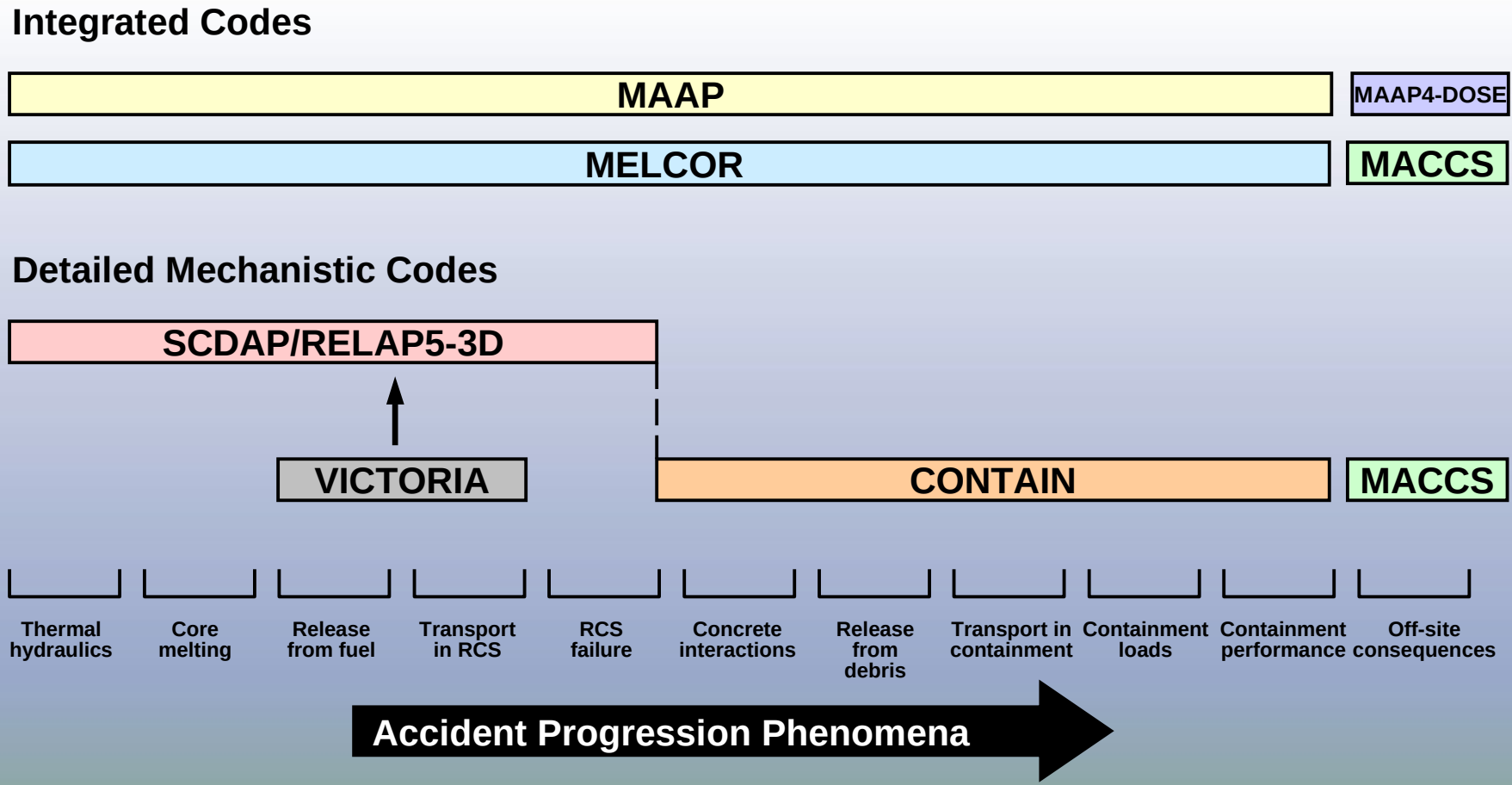
S/R5-3D Capabilities

SCDAP/RELAP5-3D Embodies Understanding of Severe Accident Processes



S/R5-3D Capabilities

Approximate Accident Phenomena Covered by U.S. Severe Accident Computer Codes



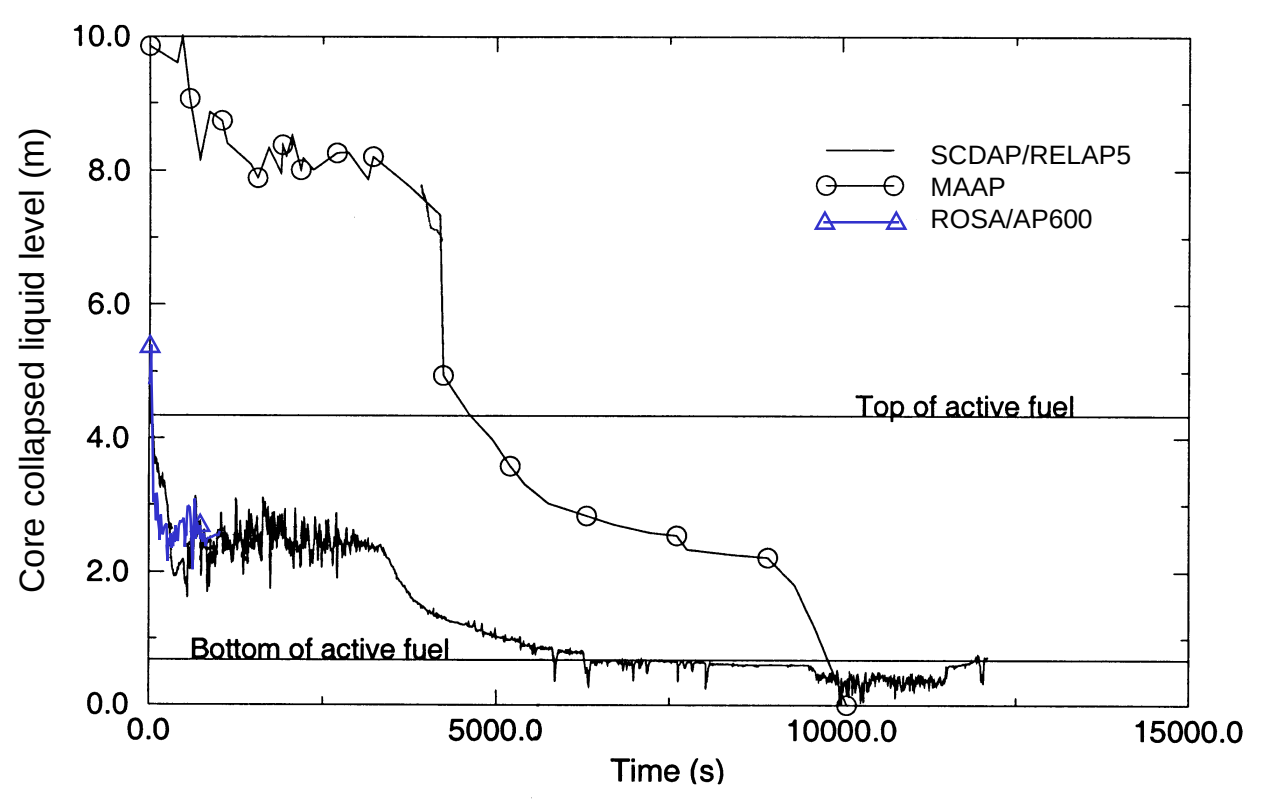
S/R5-3D Comparisons

Code Models and Assumptions Impact 3BE AP600 Analysis Results

Phenomenon	SCDAP/RELAP5-3D	MAAP	MELCOR
RCS Depressurization Model	Ransom/Trapp critical flow model (results consistent with ROSA/AP600 data)	Single phase critical flow model (unexplained mass retained in RCS)	Two-phase critical flow model (with user supplied discharge coefficients)
Fuel melting	At 2870 K due to eutectic formation	At 3100 K (UO_2 melting temperature)	At user-specified temperature.
Hydrogen generation	Throughout core degradation	Until first relocation	Until cladding failure temperature.
Relocation to vessel	If crust cannot support molten material	When melting temperature is predicted	When fuel melting occurs, material relocates to core plate and is retained until core plate reaches user-specified temperature.
Debris-to-vessel heat transfer	No enhanced debris cooling (model developed, data needed to validate)	Enhanced cooling from water in user-specified gaps with user-specified heat transfer	No enhanced debris cooling (model developed, data needed to validate)

S/R5-3D Comparisons

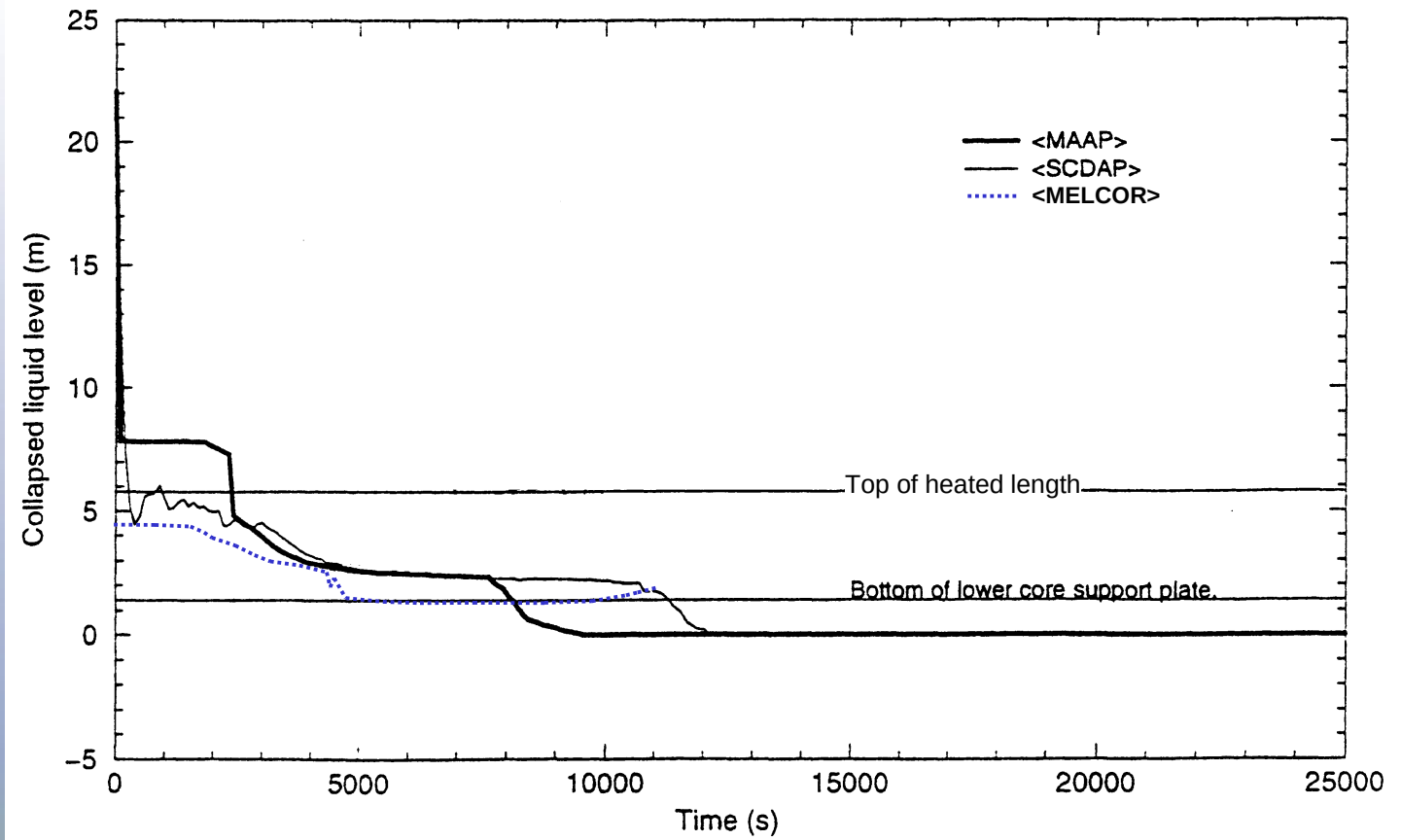
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



SCDAP/RELAP5-3D core uncovery consistent with ROSA/AP600 data.

S/R5-3D Comparisons

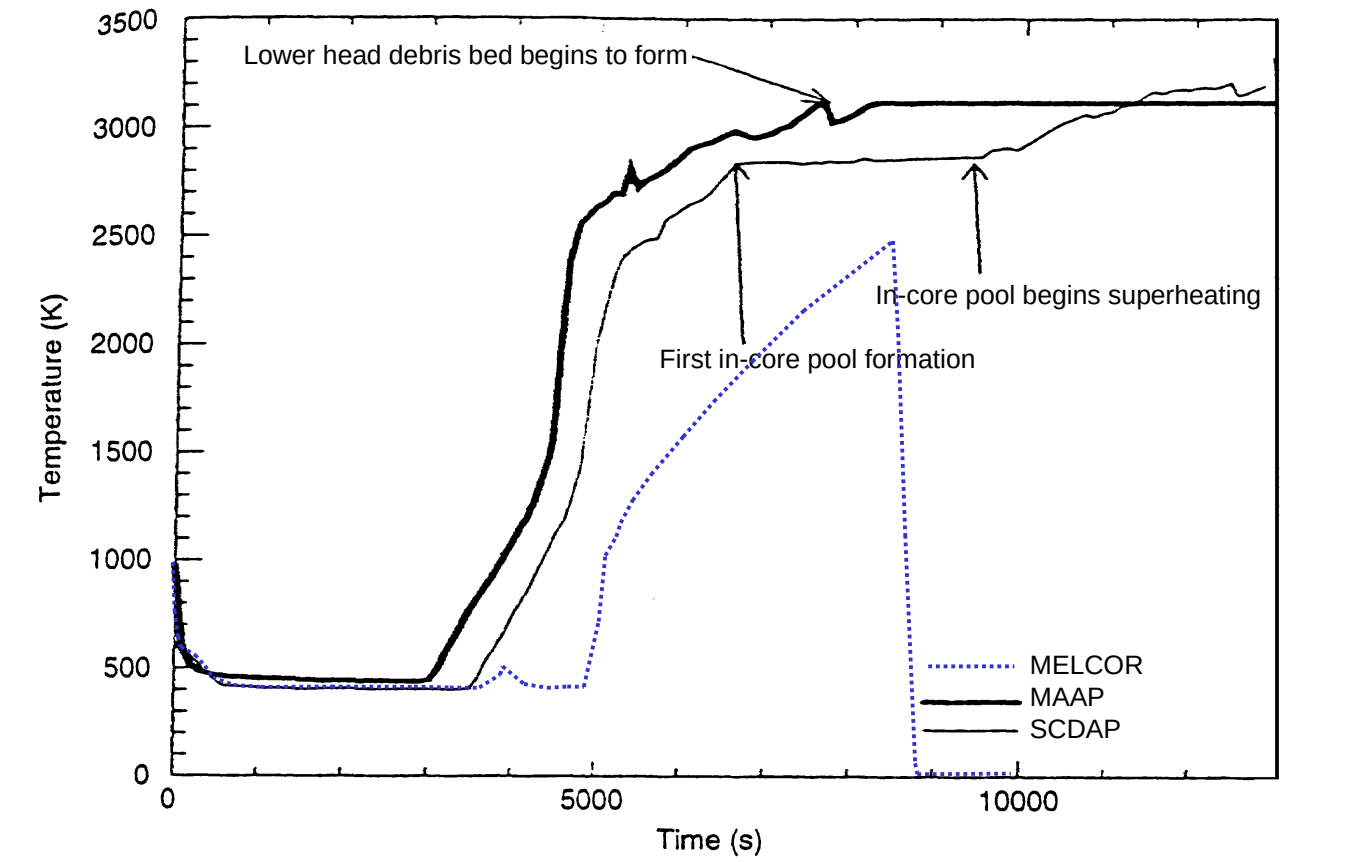
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MELCOR shows early core uncovery.

S/R5-3D Comparisons

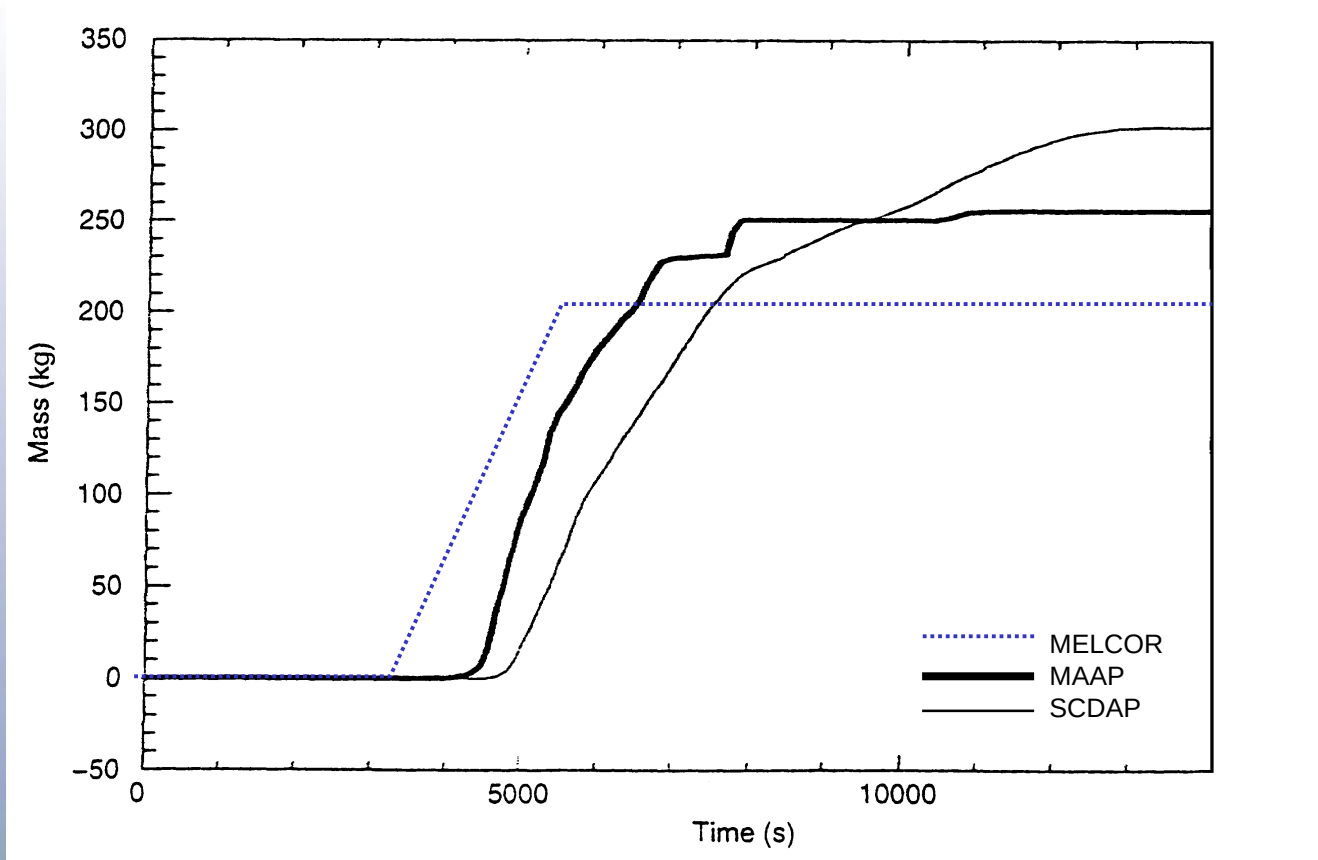
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MELCOR shows delayed core heatup despite early core uncovery.

S/R5-3D Comparisons

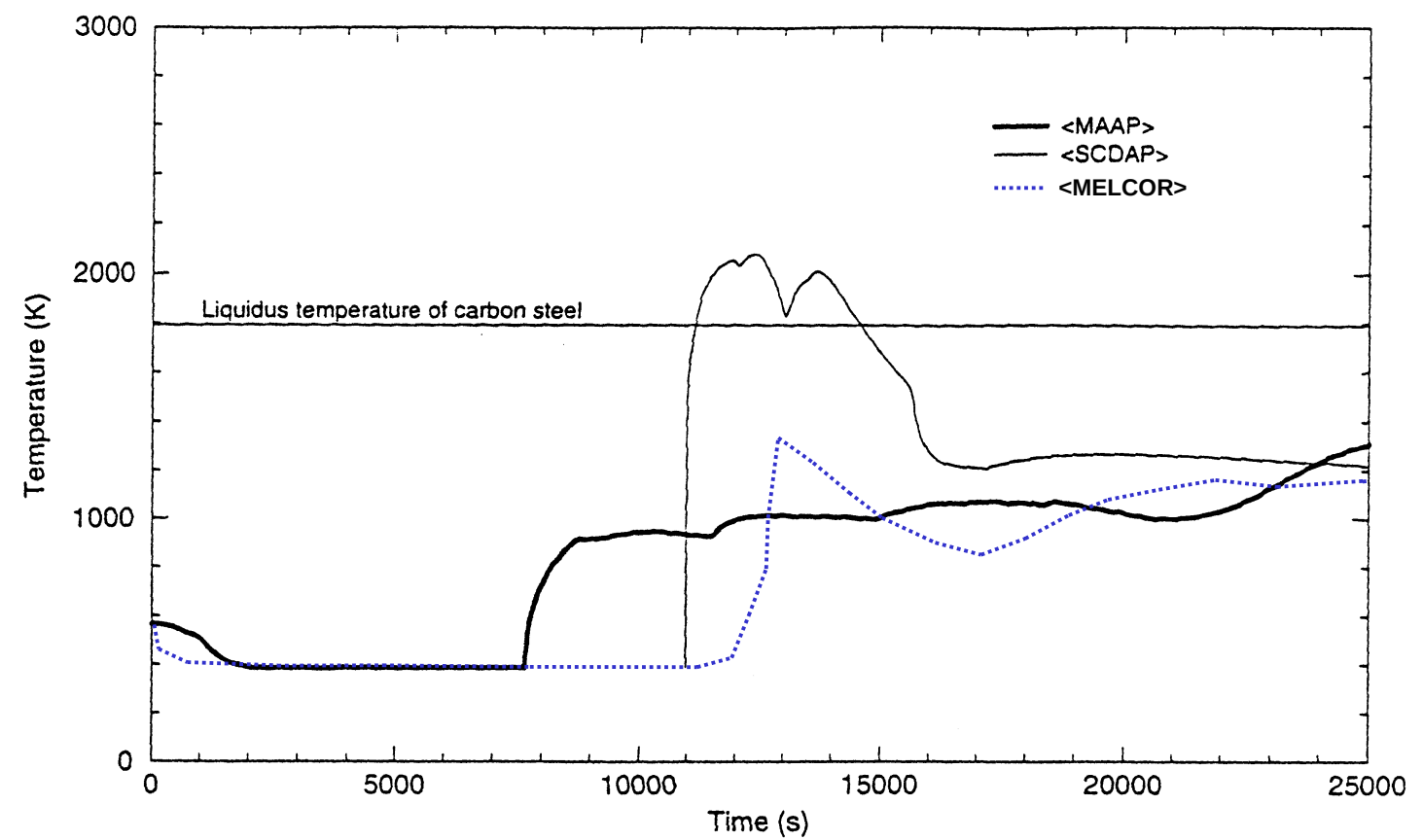
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MAAP and MELCOR predict much lower hydrogen generation.

S/R5-3D Comparisons

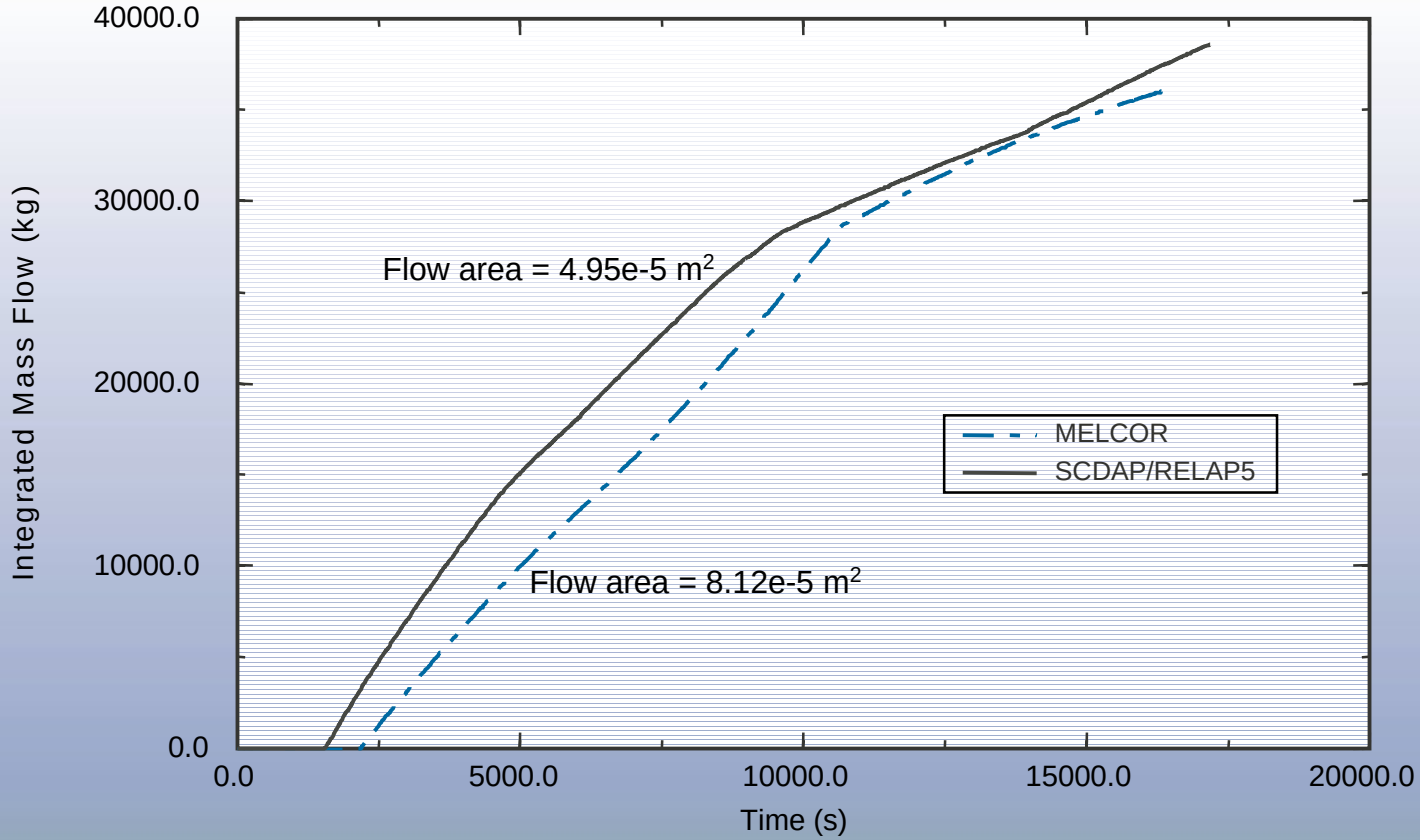
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MAAP and MELCOR predict lower debris heat load on vessel wall.

S/R5-3D Comparisons

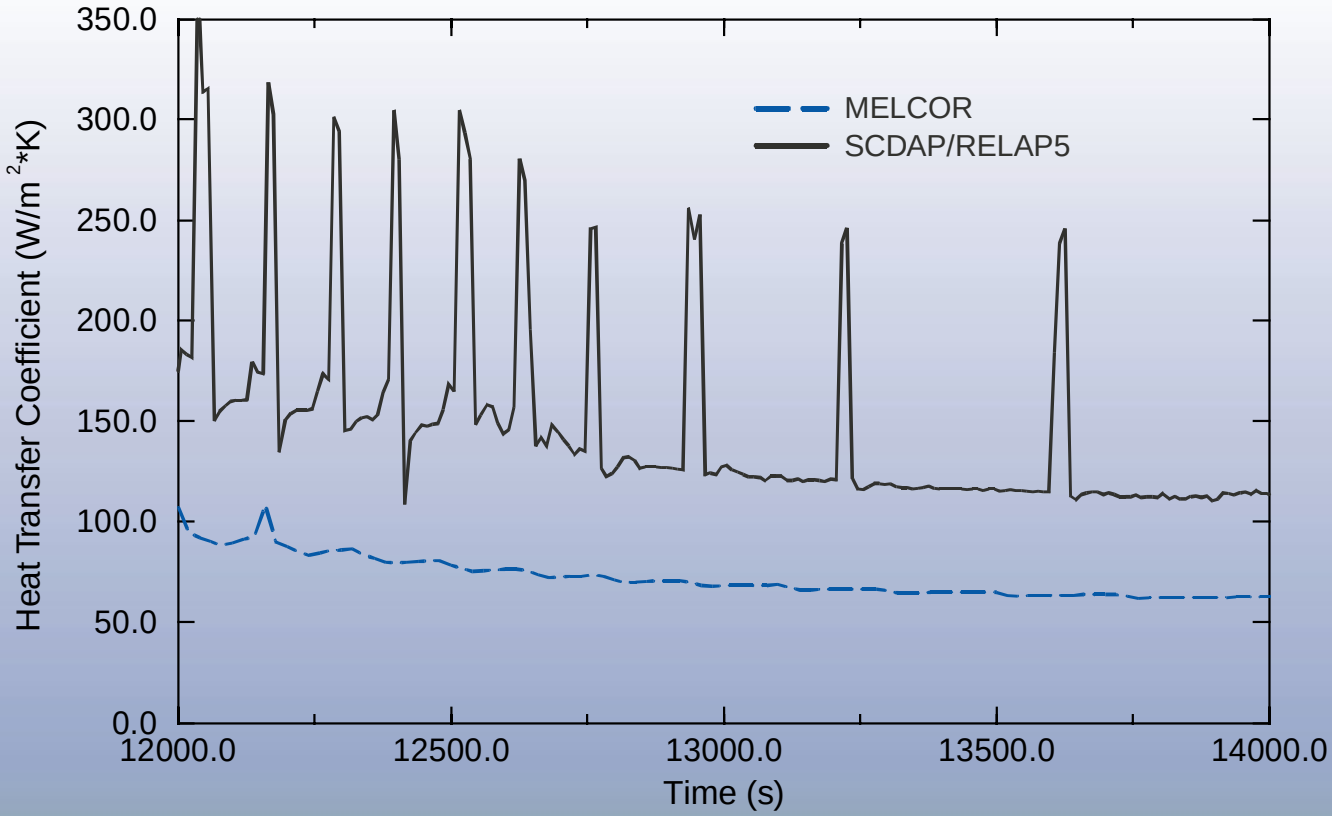
Code Models and Assumptions Impact Westinghouse PWR SBO Analysis



MELCOR requires larger flow area to match flow prediction.

S/R5-3D Comparisons

Code Models and Assumptions Impact Westinghouse PWR SBO Analysis (continued)



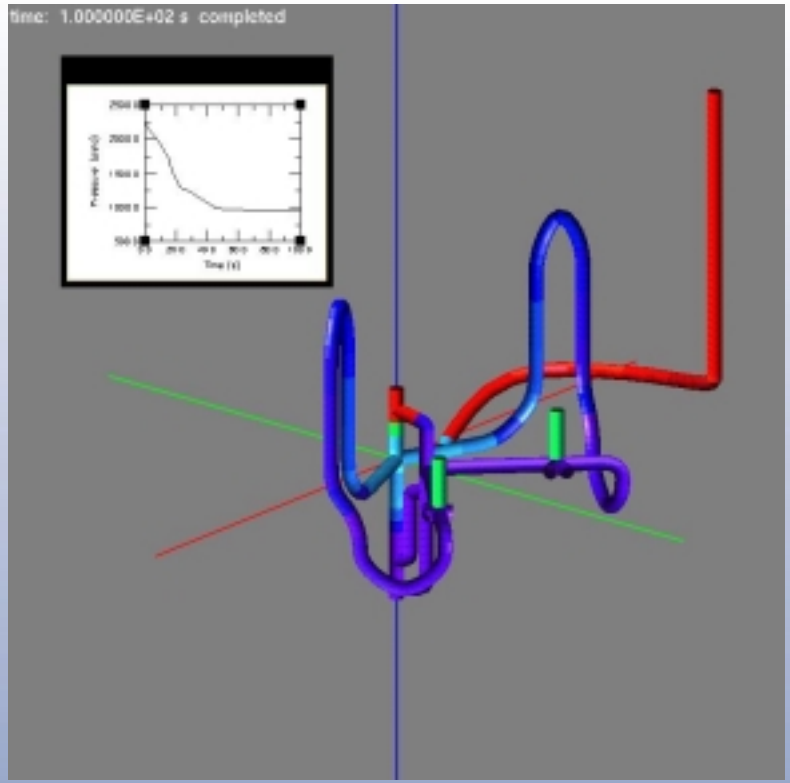
Unexplained absence of heat transfer response in MELCOR.

SCDAP/RELAP5-3D New Features

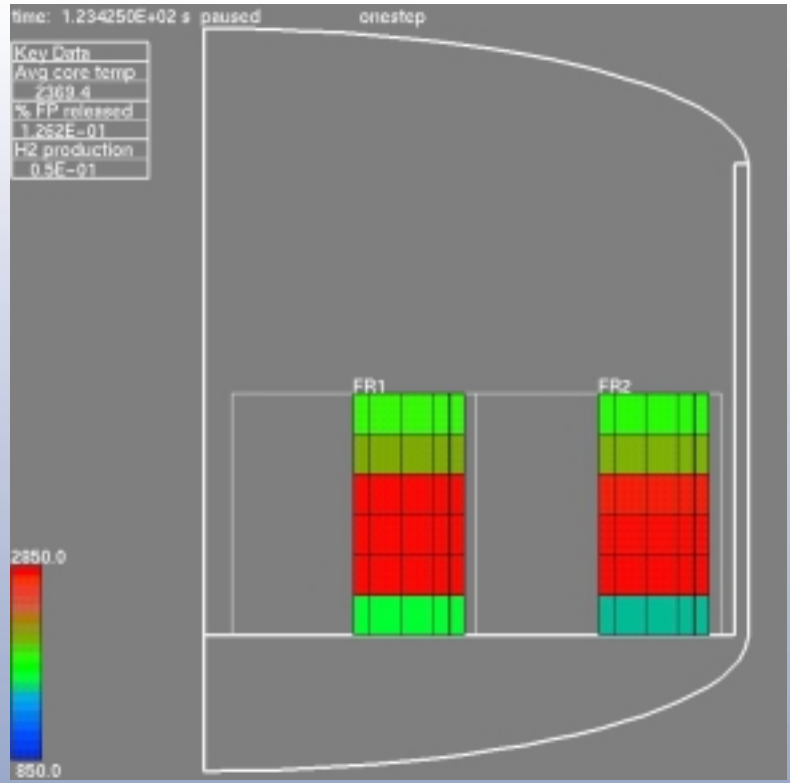
- *Linkage to RELAP5-3D providing first 3D severe accident code*
- *PVM link with FLUENT in progress*
- *Reflood modeling with fine mesh renodalization*
- *Refined gap conductance models*
- *Automatic generation of power profiles for nodalization sensitivities*
- *High burnup capabilities (allowing variation of radial power profiles as a function of core elevation)*
- *Alternate fuels capable*

S/R5-3D Features

SCDAP/RELAP5-3D GUI Allows Users to Identify Input Errors and View Run-Time Results



RELAP5



SCDAP

S/R5-3D Features

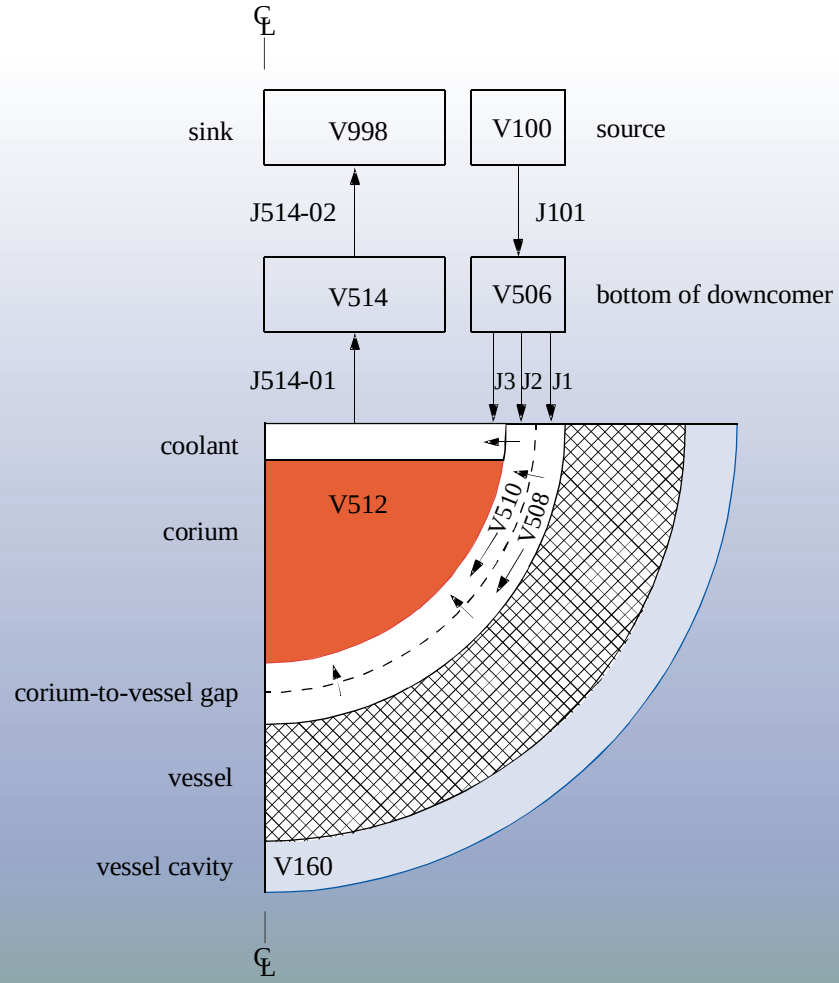
Addition of Corium-to-Vessel Gap Cooling Significant SCDAP/RELAP5-3D Enhancement

- *Evidence suggests presence of corium-to-vessel gap*
  - *TMI-2 data*
  - *JAERI ALPHA experiments*
  - *KAERI LAVA tests*
- *Gap representation critical to accurate simulation of vessel lower head thermal response*
- *SCDAP/RELAP5-3D will contain high fidelity heat transfer model (not limited to simple CHF relationship used in some codes)*

S/R5-3D Features

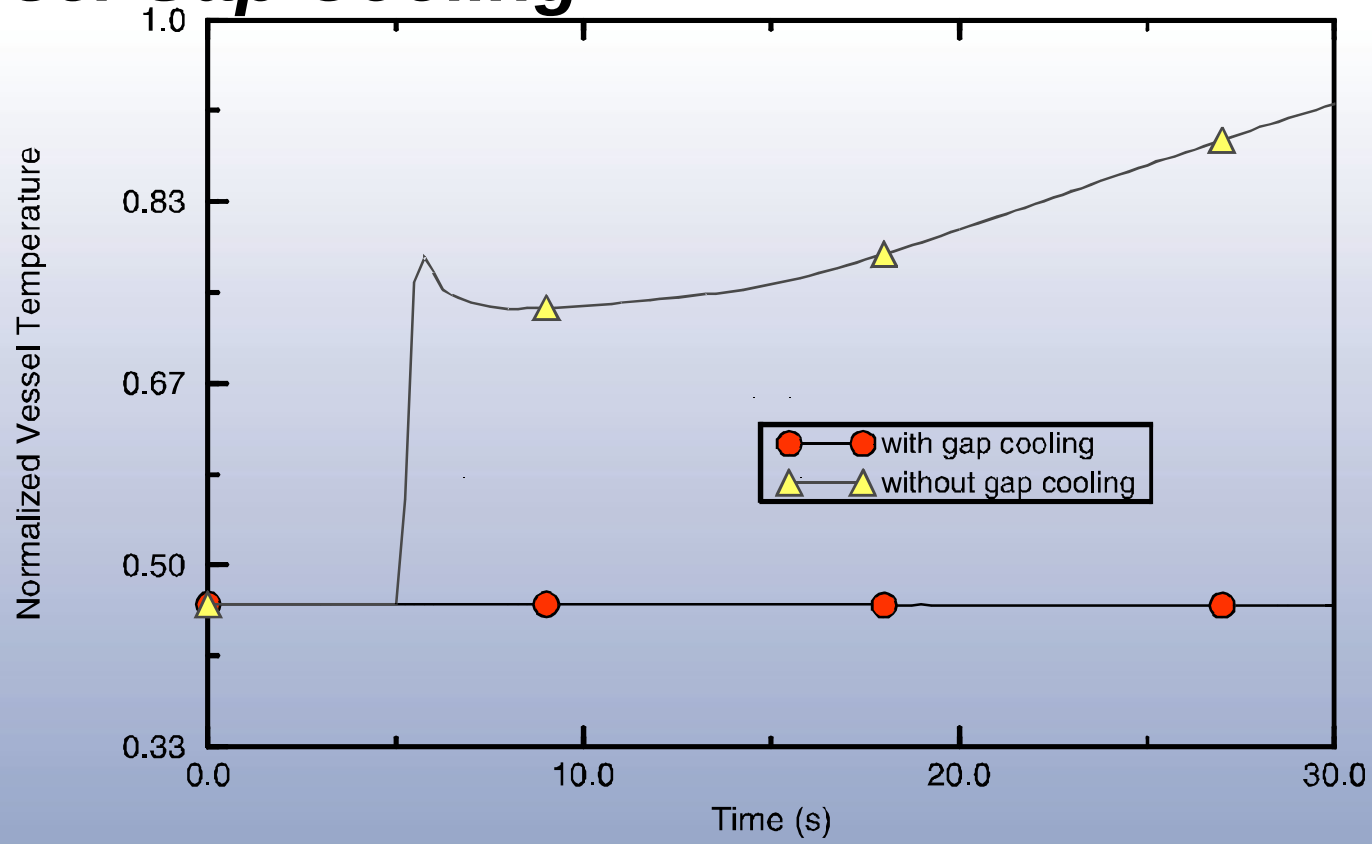
Configuration Needed for Corium-to-Vessel Gap Cooling

- *Two volume gap allowing countercurrent cooling flow*
- *Crossflow connections incorporated in finite element mesh*
- *Heat transfer correlations*
- *Without impacting corium/vessel contact resistance heat transfer option*



S/R5-3D Features

Results Indicate Significance of Corium-to-Vessel Gap Cooling



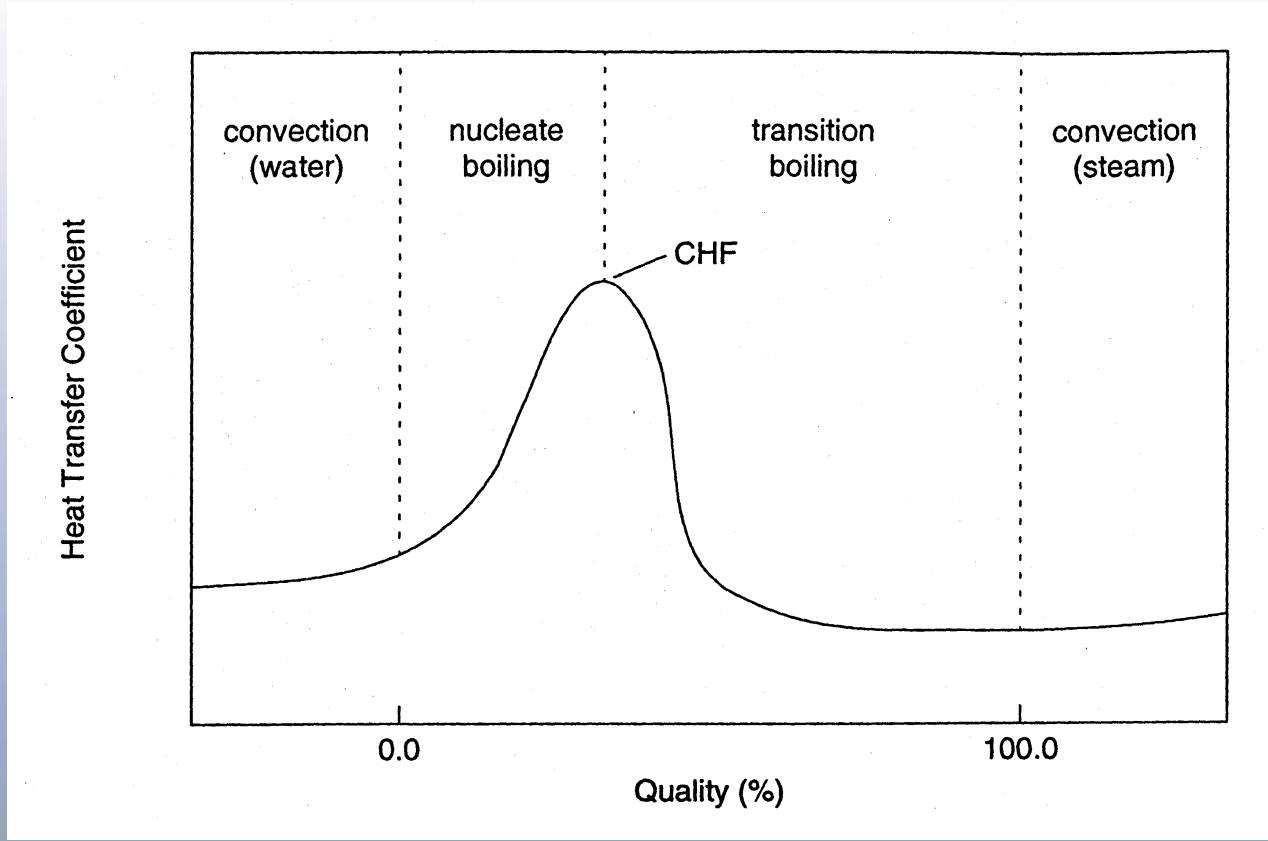
Results currently a function of RELAP5-3D correlations for pipe flow.

Planned/Proposed SCDAP/RELAP5-3D Improvements

- *Development of narrow gap flow and heat transfer correlations (from existing sources and K-INERI experiments)*
- *Core catcher modeling capabilities*
- *ERVC simulation refinements for effects of*
  - *Vessel insulation*
  - *External coatings*
  - *Heat transfer in “tap” water*

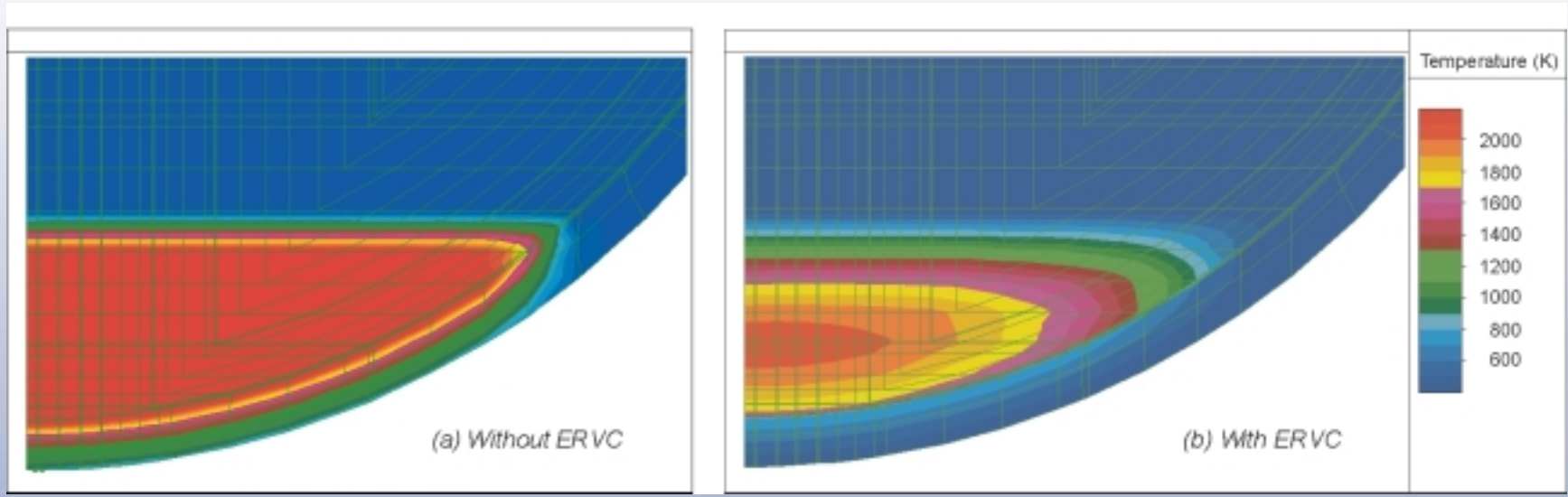
S/R5-3D Improvements

Development of Complete Narrow Gap Boiling Curve Anticipated



S/R5-3D Improvements

Current Results Reflect ERVC Effects Using Penn State Data



Other correlations will be added through the K-INERI program.

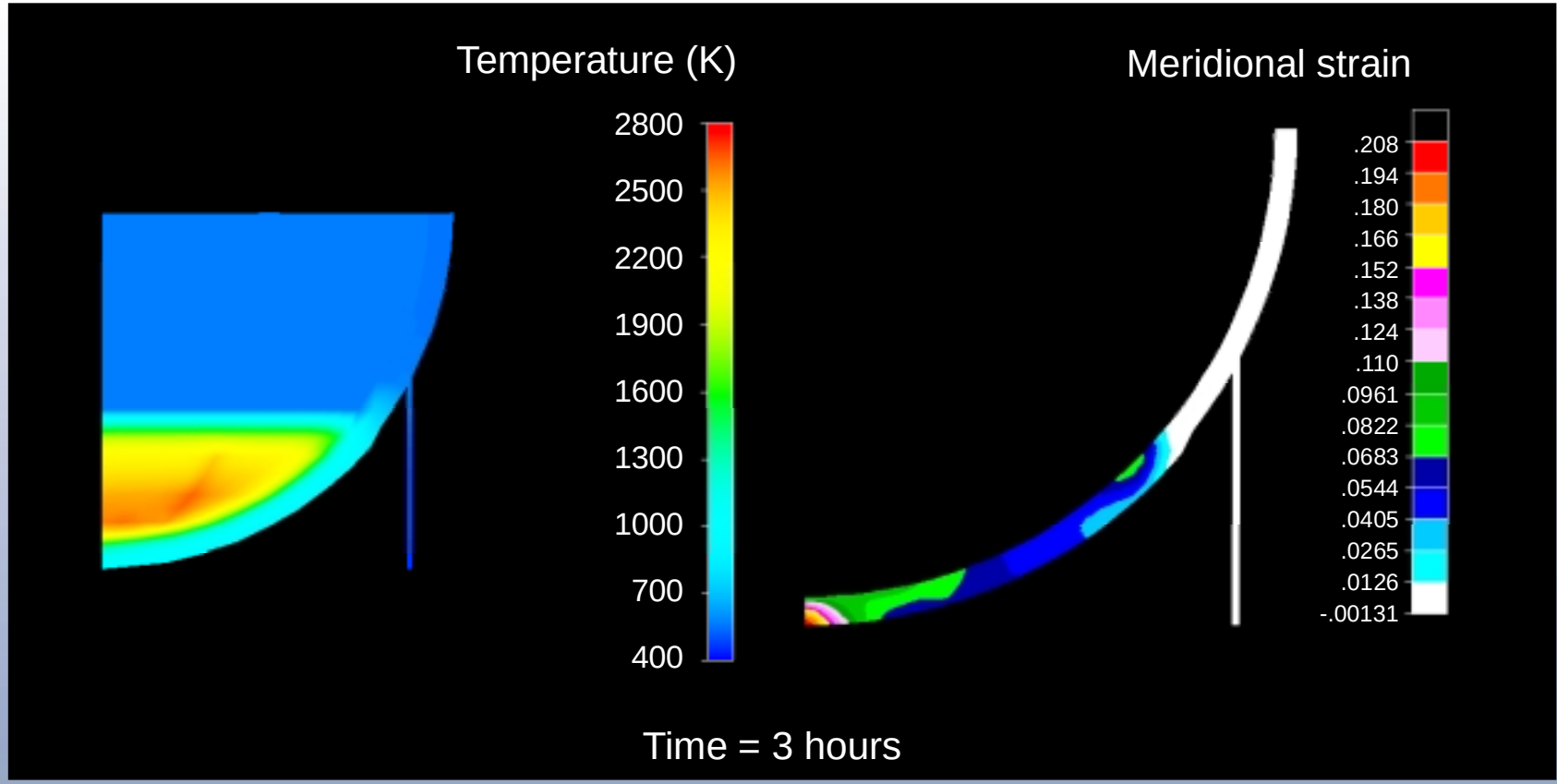
Other INEEL Capabilities

RELAP5-3D Executive Allows Flexible Integration of Best-Estimate Analysis Tools

- *RELAP5-3D executive developed in cooperation with Bettis*
- *Potential PVM linkage to RELAP5-3D might include*
  - *FLUENT for detailed flow simulation*
  - *SCDAP for core damage progression analyses*
  - *VICTORIA for fission product transport/deposition*
  - *COUPLE for detailed lower head IVR thermal analyses*
  - *ABAQUS for detailed lower head IVR structural analyses*
  - *CONTAIN for calculating containment response (originally done at INEEL and subsequently refined at Bettis)*
  - *MACCS for estimation of radiological consequences*

Other INEEL Capabilities

Coupled SCDAP/RELAP5 - ABAQUS - PATRAN Analysis Allows Detailed Structural Response

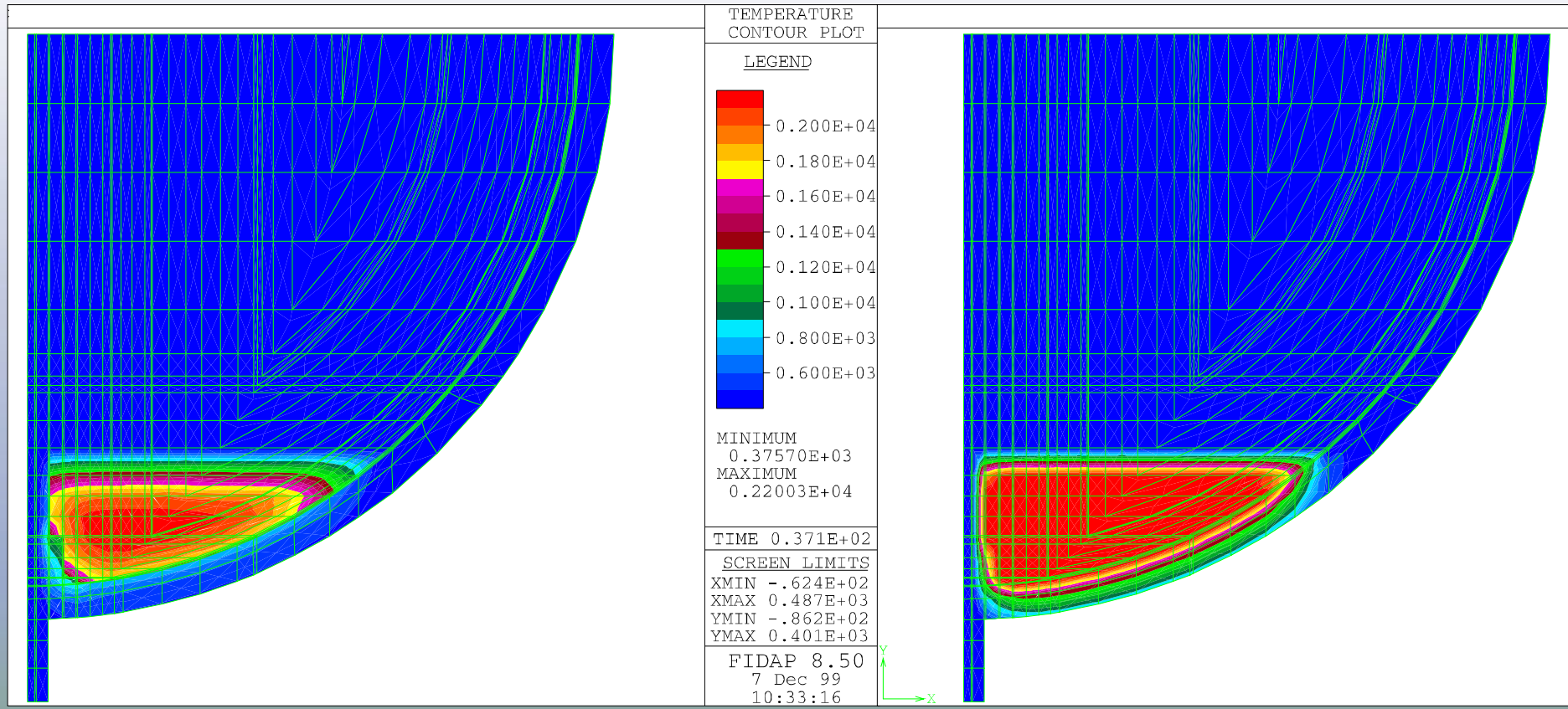


Other INEEL Capabilities

Structural Melting Sensitive to Initial Corium Temperature

Initial corium temperature 2250 K

Initial corium temperature 3000 K

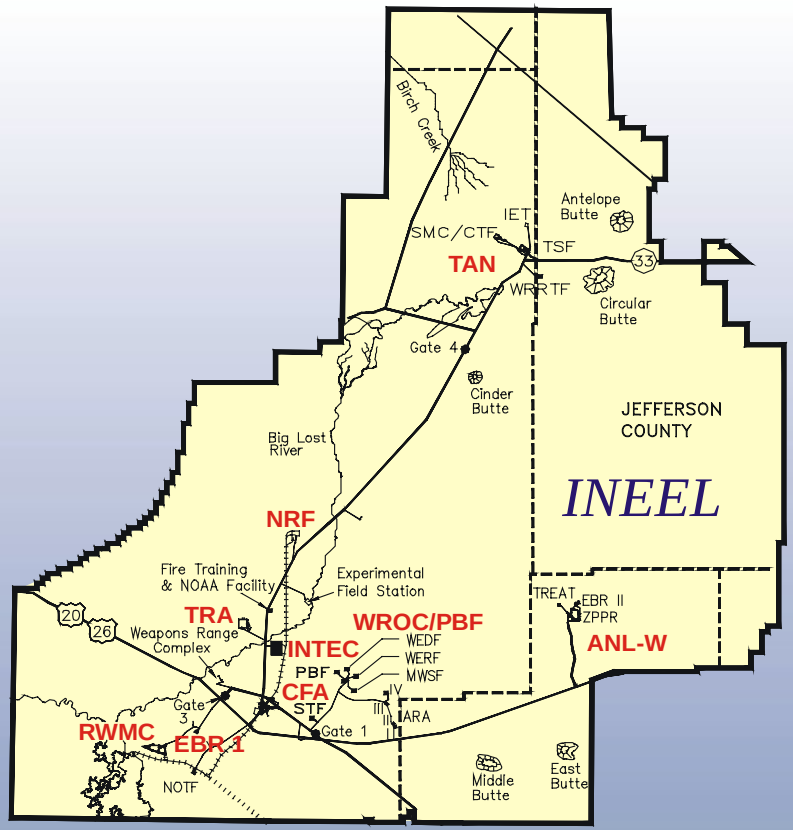


Other Related INEEL Capabilities

- Training
  - Software specific courses
    - RELAP5-3D
    - SCDAP/RELAP5-3D
    - MACCS
  - PRA courses
    - PRA basics and statistics
    - Level 2
    - Level 3
    - PRA tools (SAPHIRE, GEM, etc.)
    - Risk assessment
    - Human factors
  - Courses can also be customized to meet specific needs

Other INEEL Capabilities

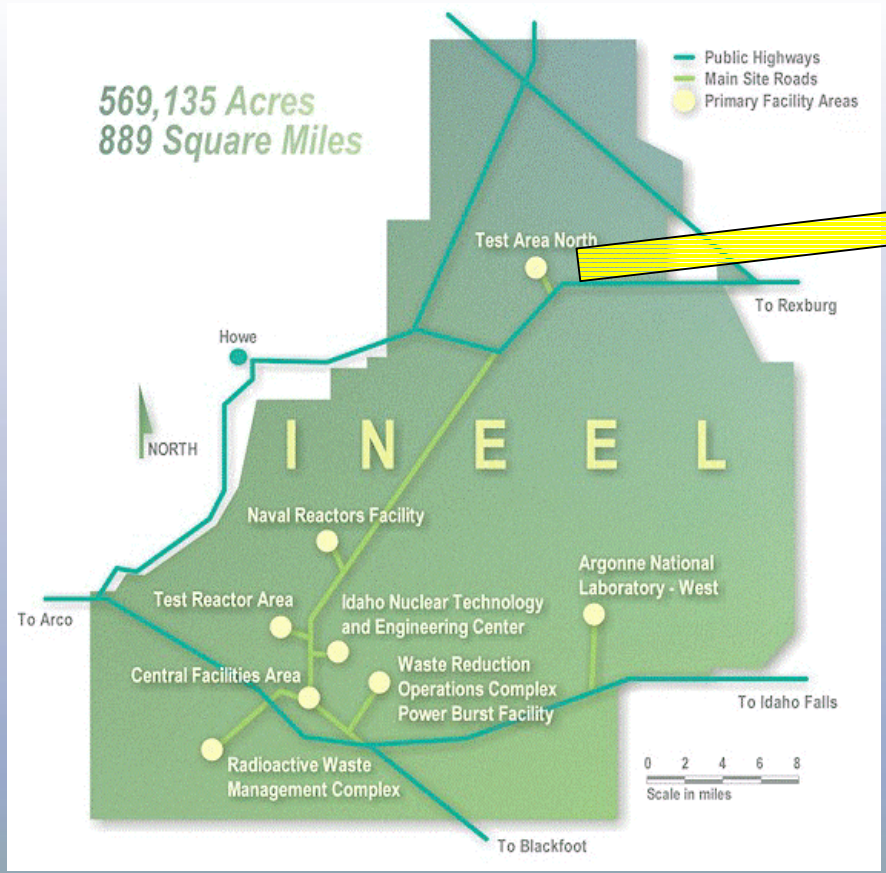
Wide Range of Experimental Facilities at INEEL



- *INEEL work conducted in the City of Idaho Falls and eight primary facility areas at the INEEL site.*
  - *Over 500 buildings*
  - *Nearly 900 square miles*
  - *Approximately 9000 employees*
- *Long history in nuclear energy technologies*
  - *52 reactors constructed*
  - *First reactor to produce electricity (EBR-I)*
  - *First reactor to light a city (BORAX III)*

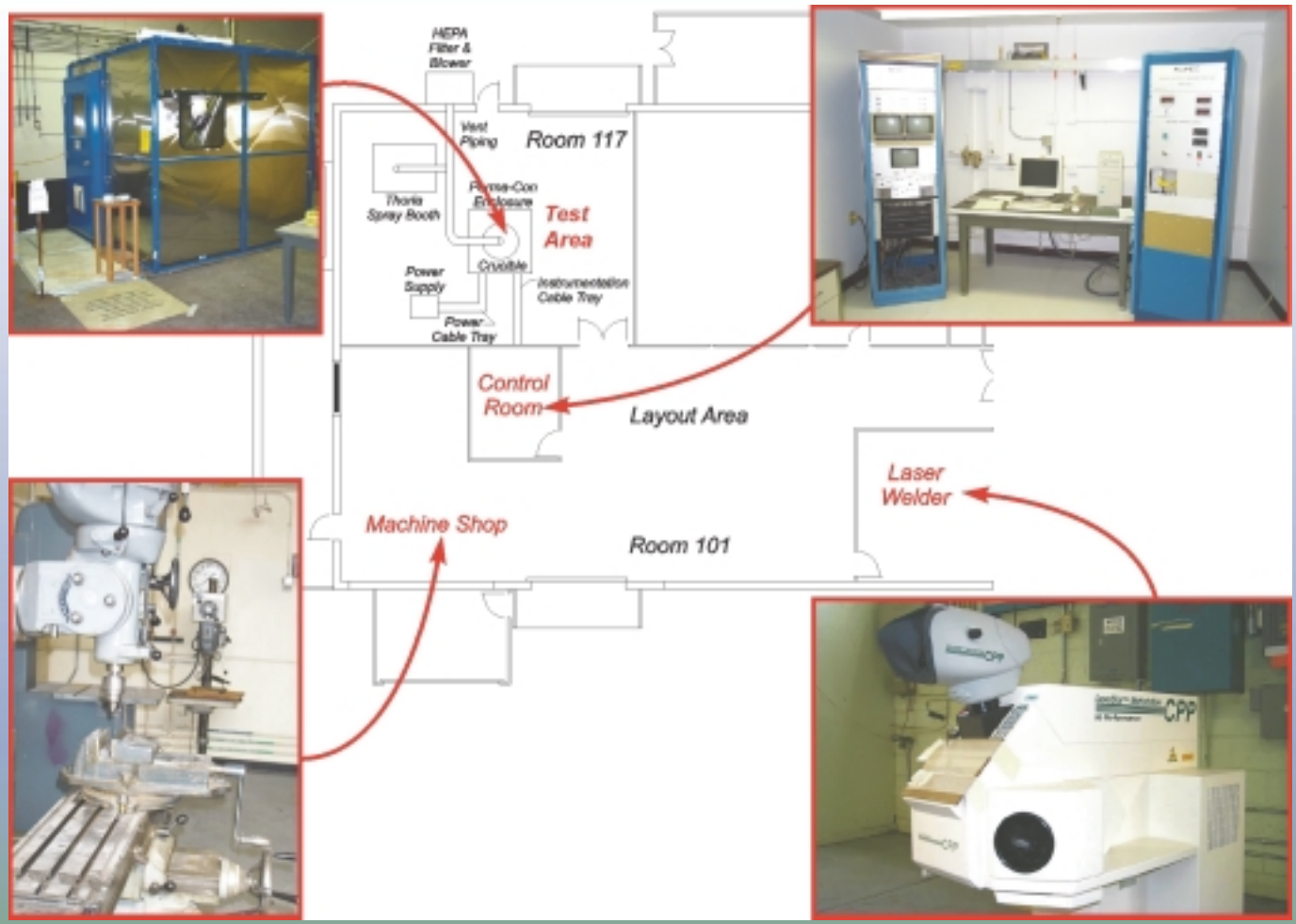
Other INEEL Capabilities

Prototypic material mini-heater tests conducted in Test Area North, Building 604



Other INEEL Capabilities

NUPEC-funded TAN 604 modifications for prototypic testing of decay heat simulator heaters



Other INEEL Capabilities

Several Heater Design Performance Tests Completed using Prototypic Materials

Summary

- *SCDAP/RELAP5-3D*
  - *Is an advanced best-estimate code for simulation of severe reactor accidents*
  - *Models provide more realistic results than the more parametric MELCOR code*
  - *Improvements at INEEL are continuing*
  - *Could be part of an integrated best-estimate analysis package through RELAP5-3D executive*
- *Related INEEL capabilities*
  - *Experimental facilities and expertise*
  - *Training*
  - *Complete analytical support*