Lockheed Martin Corporation
Sandia National Laboratories

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Demonstration of AP1000 Expertise and Capabilities

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SAND

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MELCOR Computer Code

- **MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents**
- **Broad spectrum of severe accident phenomena treated**
  - **Thermal-hydraulic response**
  - **Core heat-up, degradation, and relocation**
  - **Core-concrete attack**
  - **Hydrogen production, transport, and combustion**
  - **Fission product release and transport behavior**
  - **Impact of engineered safety features on thermal-hydraulic and radionuclide behavior**

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MELCOR Overview

- **MELCOR has been developed at Sandia National Laboratories for the USNRC**
  - **Project began in 1982**
  - **Development of new capabilities still underway**
  - **Improvement of current models is a continuous effort**
- **Major development motivation was integration**
  - **Replace collection of simple, special purpose codes**
  - **Capture feedback effects**
    - **Coupling of temperatures, release rates, and decay heating**

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Role of MELCOR

- **MELCOR was originally conceived as a PRA code**
  - **Modeling was to be as simple and fast running as possible**
  - **Uncertainties to be dealt with through sensitivity studies**
  - **Substantial user flexibility to be allowed**
- **MELCOR has developed into a state-of-the-art tool for source term calculations**

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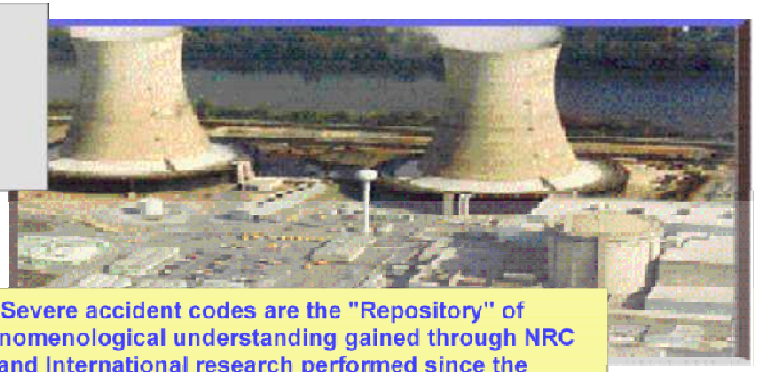
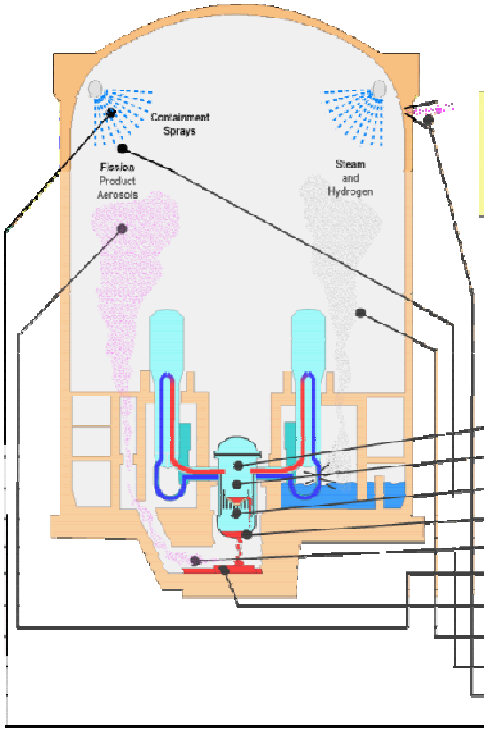
MELCOR Computer Code

Modeling and Analysis of Severe Accidents in Nuclear Power Plants





Severe accident codes are the "Repository" of phenomenological understanding gained through NRC and International research performed since the TMI-2 accident in 1979

***Integrated* models required for self consistent analysis**

Important Severe Accident Phenomena

	MELCOR	CONTAIN	VICTORIA	SCDAP RELAP5
Accident initiation	■			■
Reactor coolant thermal hydraulics	■			■
Loss of core coolant	■			■
Core meltdown and fission product release	■		◢	■
Reactor vessel failure	■			■
Transport of fission products in RCS and Containment	■	■	■	
Fission product aerosol dynamics	■	■	■	
Molten core/basemat interactions	■	■		
Containment thermal hydraulics	■	■		
Fission product removal processes	■	■	■	
Release of fission products to environment	■	■	■	
Engineered safety systems - sprays, fan coolers, etc	■	■		
Iodine chemistry, and more	■			

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MELCOR Computer Code

- **Code Validation/Verification**
  - **TMI-2 Accident**
  - **Spent Fuel Pool Ignition Tests**
  - **Fission product release and transport**
    - **PHEBUS**
    - **VERCORS**
  - **LOFT**
    - **Simulated many of the primary system and core thermal-hydraulic conditions expected during a Pressurized Water Reactor accident**

MELCOR phenomenological understanding represents roughly $0.5 billion in NRC and international research

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MELCOR Computer Code

- Code Validation/Verification (continued)
  - NUPEC
    - Containment thermal hydraulic experiments
  - NEPTUN
    - Boil-off experiments
  - VANAM
    - Advanced aerosol tests in scaled containment
      - Varying thermal-hydraulic conditions
      - Mixed hygroscopic/non-hygroscopic condensation aerosols
  - LACE
    - Aerosol deposition tests

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AP1000 Experience

- **Investments have been made to improve AP1000 MELCOR input deck**
  - **Original input deck was an AP600 model**
  - **Model updated to AP1000 for MELCOR version 1.8.5**
  - **Model converted to MELCOR version 1.8.6**
    - **Added hemispherical Lower Head geometry**
    - **New COR package record information added**
      - **New records for core baffle and formers**
    - **Larson-Miller creep rupture modeling added**

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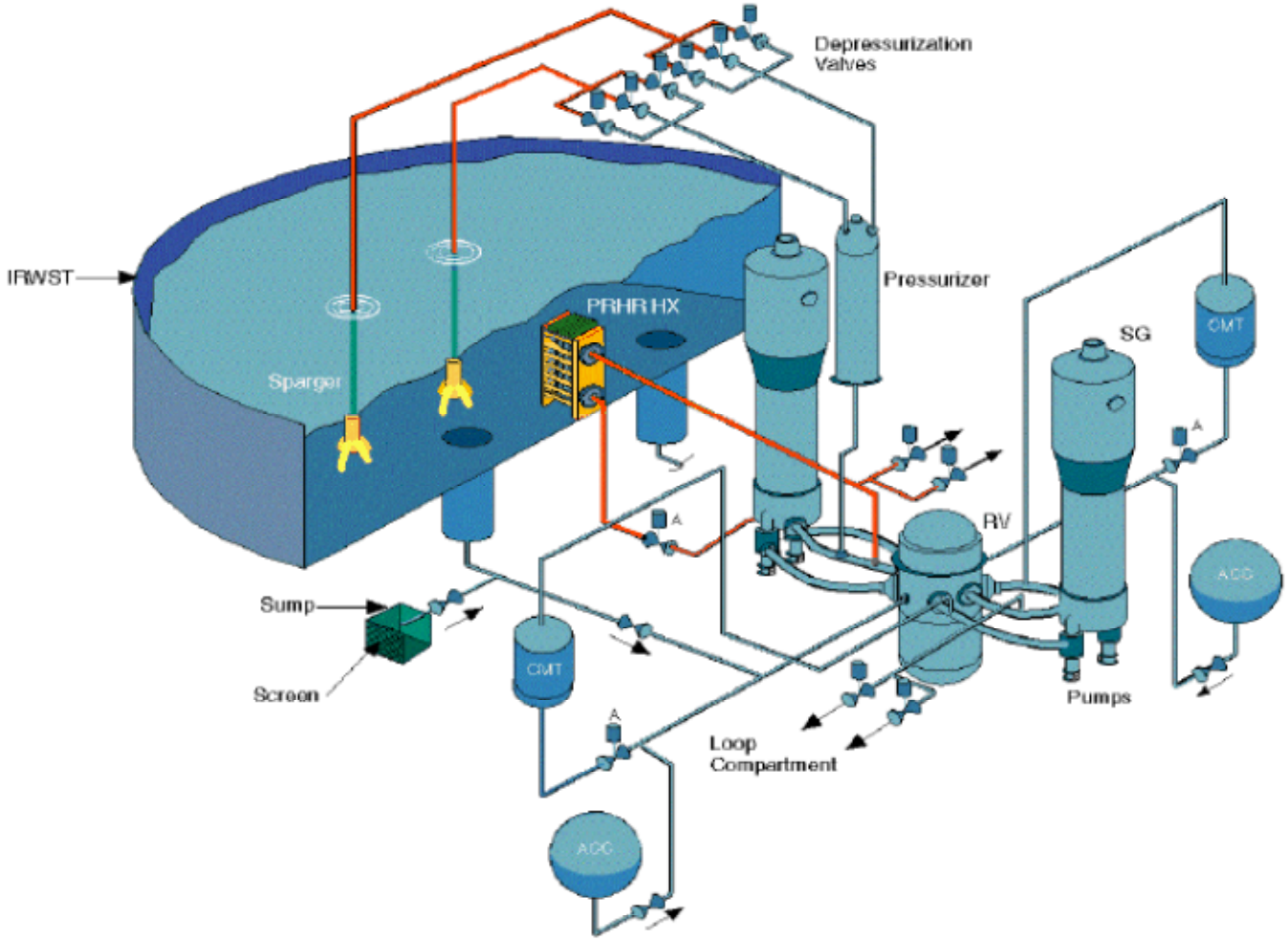
AP1000 Experience

- **AP1000 MELCOR Model Information**
  - **Primary side**
    - **Both loops explicitly modeled**
  - **Secondary side**
    - **Both loops explicitly modeled**
  - **Containment**
  - **Safety Systems**
    - **Automatic Depressurization System (ADS)**
    - **Core Make-up Tanks (CMT)**
    - **Accumulators**
    - **In-containment Refueling Water Storage Tank (IRWST)**
    - **Passive Residual Heat Removal System (PRHR)**
    - **Feedwater systems (MFW and FWS)**
    - **Passive Containment Cooling System (PCS)**
    - **Igniters**
    - **Containment Sprays**
    - **Passive Autocatalytic Recombiners (PARs)**

AP1000 Passive Safety



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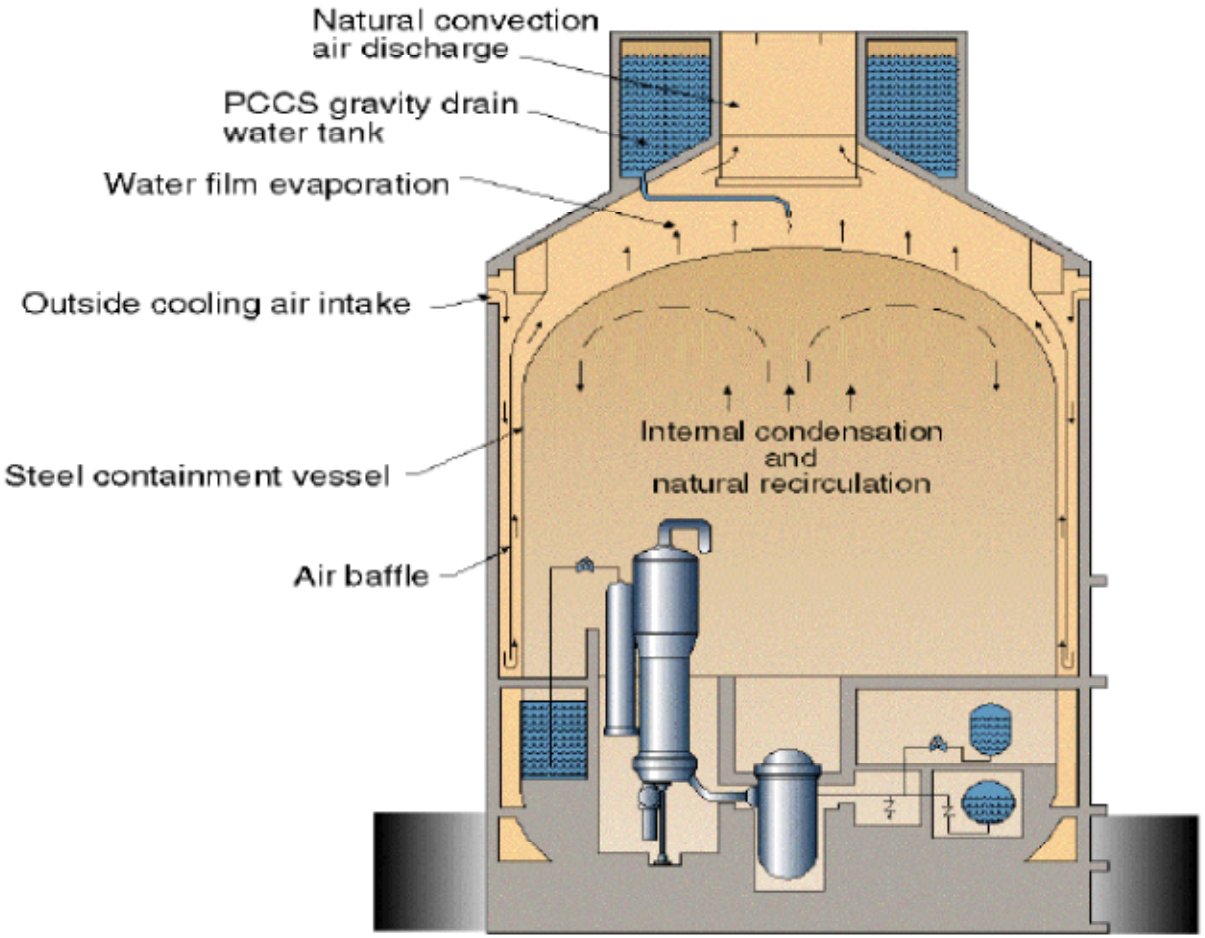
AP1000 Passive Safety



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AP1000 Model Flexibility

- **Flexibility defining accident scenarios and initiating events**
  - **Safety system availability can be toggled on/off to achieve desired accident scenario**
  - **User can specify Initiating Event**
    - **Steam Generator Tube Rupture**
    - **Loss-of-Coolant Accident**
      - **Break size and location can be specified (e.g., 3BE)**
    - **Spurious system activation**
      - **Automatic Depressurization System**
    - **Station Blackout**

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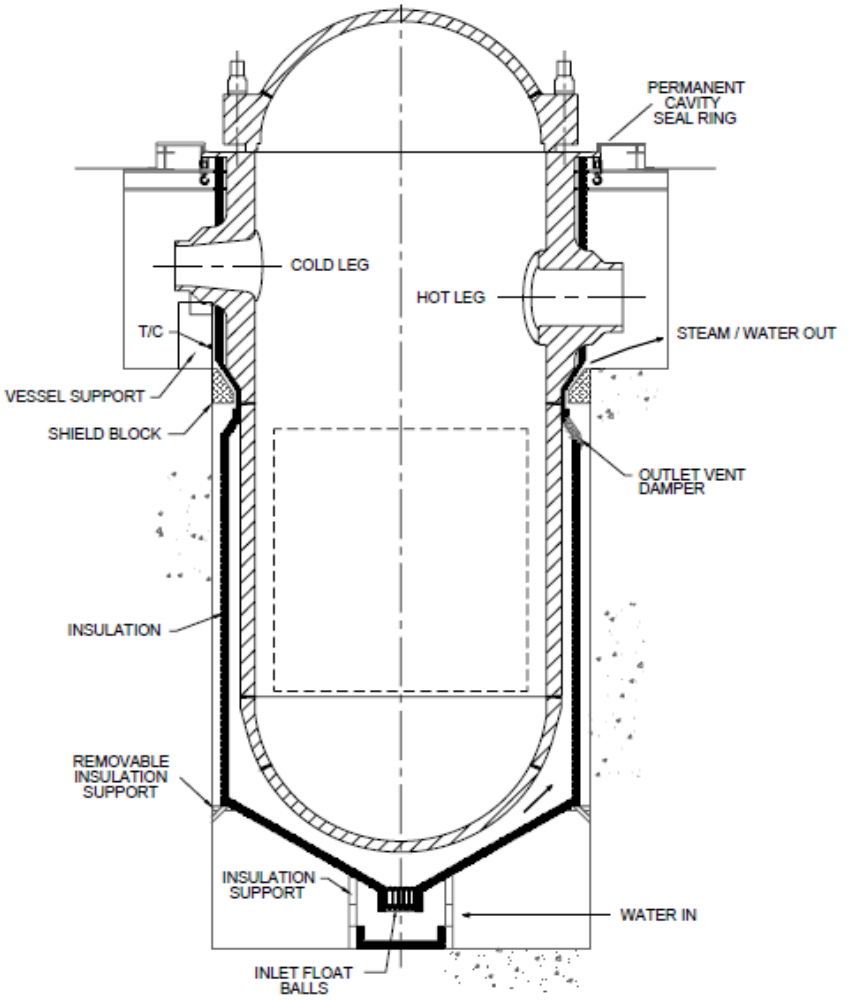
AP1000 Experience

- **Confirmatory In-Vessel Retention analyses have been principle focus of AP1000 calculations at Sandia National Laboratories**
- **In-Vessel Retention strategy**
  - **Retain all core materials inside the vessel**
    - **Flood cavity to keep lower head cool**



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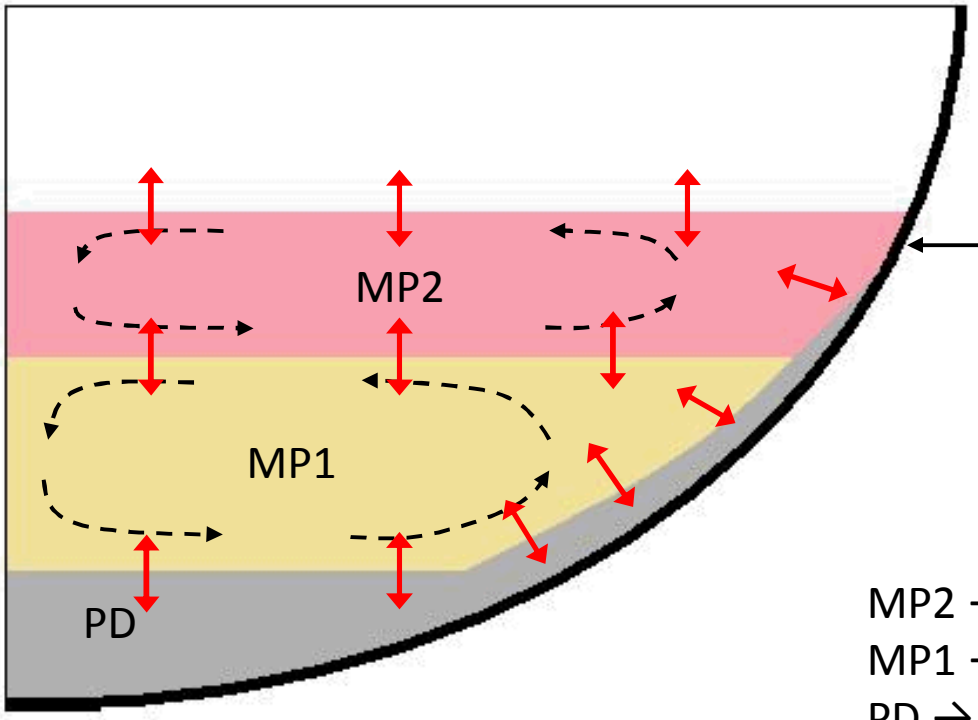
Molten Pools



Heat focusing occurs here because of metallic molten pool thermal conductivity

MP2 → Metallic Molten Pool
MP1 → Oxide Molten Pool
PD → Particulate Debris

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Molten Pools

- Two distinct molten pools allowed in Lower Plenum
  - Oxide
  - Metallic
- Largest contiguous molten pools are modeled as convecting pools and transfer heat to
  - Substrate materials including the Lower Head
  - Fluids (water or steam)
  - Structural components
- New MELCOR models added to
  - Predict heat transfer coefficients to the substrate material
  - Heat transfer between pools
  - Heat transfer to surroundings

AP1000 In-Vessel Retention

- **In-vessel retention analyses have typically been done in the described steady state condition**
  - **Thickness of metallic layer**
  - **Decay heat**
  - **Vessel size**
  - **Amount of core relocation**

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AP1000 In-Vessel Retention

- **We want to understand the transient convective conditions as molten pools are formed or grow from relocation events**

- **To our knowledge, MELCOR is the only severe accident code to explore integrated transient thermal analyses of IVR**

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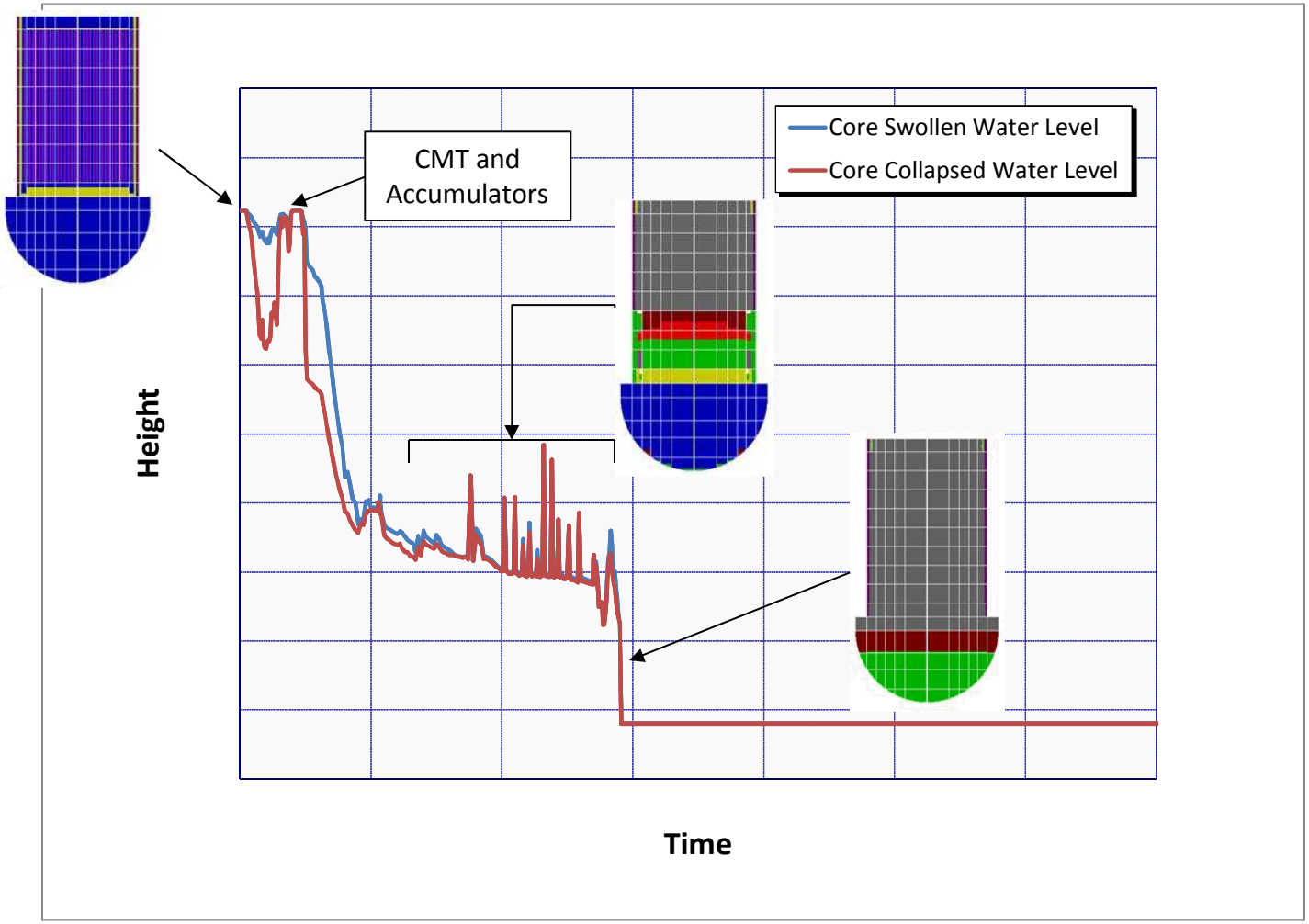
AP1000 Example Problem



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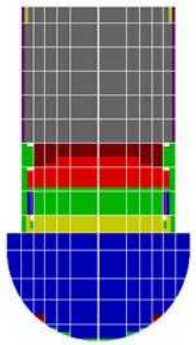
AP1000 Example Problem



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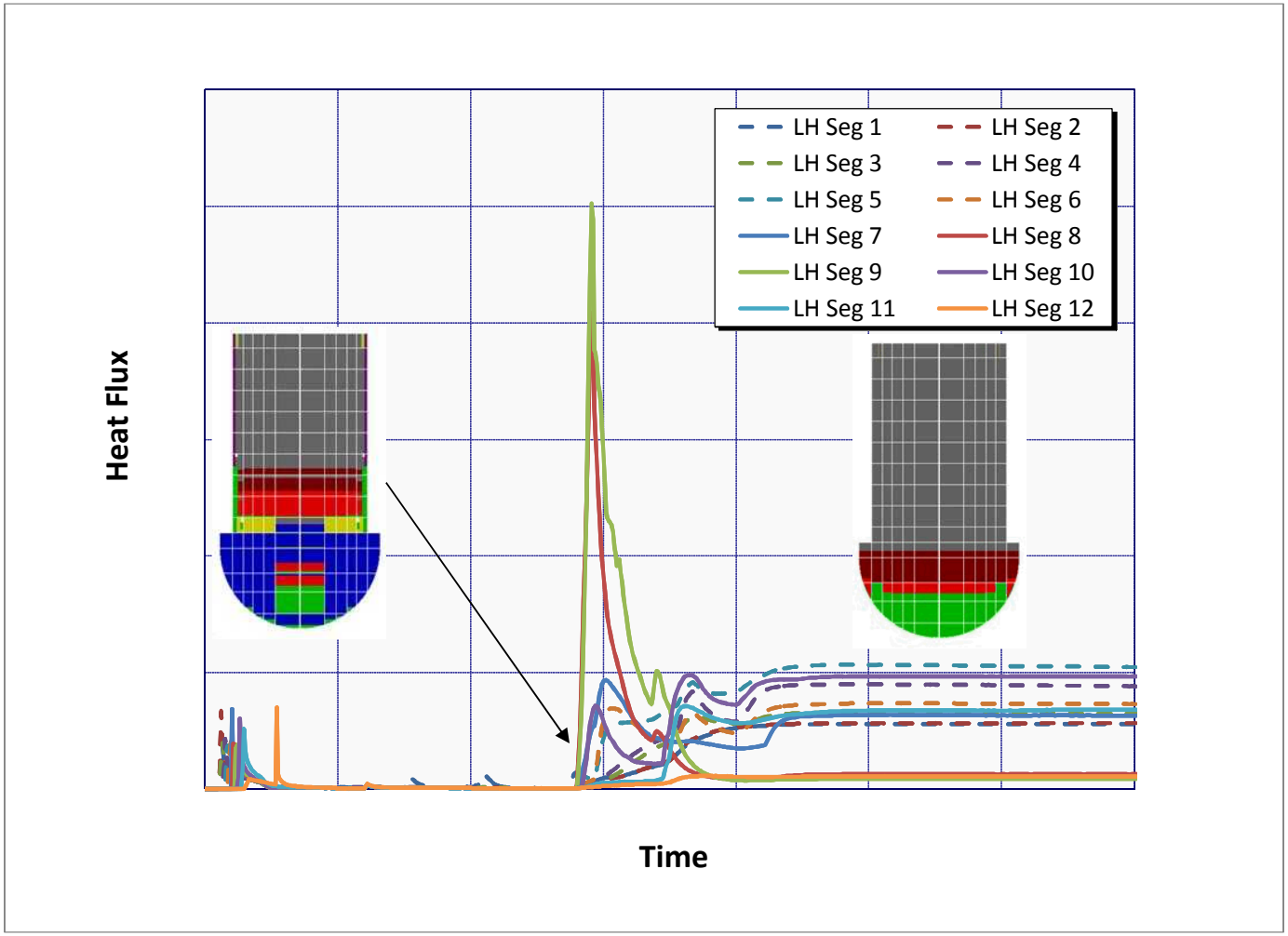
AP1000 Example Problem



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Summary of Capabilities

- **Ability to model specific reactor designs**
  - **Safety systems**
- **Accident scenario definition is flexible**
  - **Initiating Events**
  - **System availability**
- **Mechanistic understanding of phenomenological principles surrounding AP1000**

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