MELCOR/SCALE for HTGRs
2019 SCALE Users' Group Workshop
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W. Wieselquist
NRC support

- **MELCOR**
  - severe accident analysis
  - **TRACE**
    - design basis plant behavior
  - **FAST**
    - fuel performance

**SCALE (ORNL)**

- Spent fuel calorimeter measurements
- Actinides reactivity worth in spent fuel
- Fission products reactivity worth in spent fuel
- Radiochemical isotopic assays of HI BU SNF
- MOX cycle exposure data
- HTGR criticality – neutronics operating and safety parameters

**PARCS (Univ. of Michigan)**

- Reactor Kinetics
- Core Design/Follow
- Flow Distribution
- Peaking Factors
- Reactivity Coefficients

**CLAB (Sweden)**

- **HTC CRITICALS** (France)
- **FP CRITICALS** (France)
- **MALIBU/REBUS ARIANE CSN TAKAHAMA Domestic Programs**
- **St. Laurent MALIBU/REBUS**
- IRPhE8/OECD: HTR (Japan) HTR10 (China) PROTEUS (Switzerland) PBMR400

**SCALE (ORNL)**

- Nuclear data
- Reactor physics
- Criticality safety
- Radiation shielding
- Sensitivity and uncertainty
- Hybrid methods
- Verification and validation
- User interfaces

**10CFR72**

- NMSS/SFST Technical Basis for Decay Heat R.G. 3.54

**10CFR71**

- NMSS/SFST Technical Basis for PWR BUC Interim Staff guidance ISG-8 & BWR BUC

**10CFR72**

- NRR Catawba MOX Lead Test Assembly

**10CFR80.68**

- NRR/NRO Technical Basis for BUC for Spent Fuel Pool Criticality Safety

**10CFR72**

- NRR Licensing Amendments (i.e., MELLLA+)

**NMSS/FCSS**

- Fuel Cycle Analysis

**NMSS/SFST**

- HBU Fuel for Storage and Transportation Casks Criticality and Decay Heat

**NRR**

- Non-LWR reactors

**NRO**

- New Reactor Design (ESBWR, AP1000, APR1400, NuScale, …)

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- New Reactor Design (ESBWR, AP1000, APR1400, NuScale, …)
Reactor physics confirmatory calculations at the NRC

**ENDF/B**
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, etc.

**AMPX**
Validated cross section libraries; depletion and decay data

**TRITON / Polaris**
Transport and depletion in 1D, 2D, and 3D for LWR, ATF, and nonLWR

**ORIGEN / ORIGAMI**
Depletion, activation and decay
Reactor-specific radioactive source term characterization

**CAMP**
Advanced core simulator
Neutron flux solver and depletion

**PARCS**
System level temperature distributions and feedback

**TRACE**
Temperature distributions for gas reactors

**FAST**
Fuel performance

**AGREE**
Temperature distributions for gas reactors

**MACCS2**
Offsite consequence analysis

**MELCOR**
Severe accident analysis and mechanistic source terms

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SCALE for MELCOR/MACCS (LWRs)

Severe accident data generation with SCALE for LWRs

1. accumulate/curate nuclear data (years of data expert time)
2. develop methods (years of code developer time)
3. perform decay heat, isotopics validation (months of analyst time for a specific data set)
4. analyze operating history sensitivity for a specific reactor fuel, e.g. effect of control rods inserted during depletion (months of analyst time)
5. analyze sensitivity of a specific accident scenario analyze to modeling details, e.g. model axial spectral effect in fuel (weeks of analyst time)
6. generate isotopics at various decay times with uncertainty/bias envelopes (weeks of analyst time)
Development of Evaluation Models for Advanced Reactor Severe Accident Analysis

- **Priorities**
  - HTGR
  - SFR
  - FHR/MSR

- **Strategy**
  - start with TRITON
  - develop new ORIGEN libraries for fast analysis

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**Reactor Physics**
- Evaluated Nuclear Data File (ENDF-B/VII+)
- Cross-Section Library Generation (AMPX)
- Reactor Physics Simulation (SCALE)
- Reactor- and State-specific Libraries for Rapid Analysis

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**Evaluated Nuclear Data File**
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**Fission Product Preprocessing**
- Thermo-Fluids Steady State (MELCOR)
- Core-Wide FP Release & Distribution (MELCOR)
- System-Wide FP Distribution (MELCOR)
- Spatial Distribution of Fission Products, Circulating Activity

**LBE Transient Analysis**
- System Accident Analysis (MELCOR)
- Accident Progression & Source Term
- Consequence Analysis (MACCS)
- Dose, Health Effects, Economic/Societal Consequences

**Steady-State Initialization**
- FP Speciation, vaporization, and chemistry
- System-Wide Radionuclide Distribution (MELCOR)
- Spatial Distribution of Fission Products, Circulating Activity

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**HTGR/FHR**
- Endotoxin

**LWR/SFR/HTGR/FHR/MSR**
- HTGR/FHR
- LWR/SFR
- MSR
Phenomenology and Release Paths

LWR
- Primary System
  - Deposition / Condensation / Chemisorption
  - FP Release
  - Resuspension / Revaporization
- Vessel Leak
- Bubble Transport / Pool Scrubbing
- Release of RNs and Aerosols
- Molten Core Concrete Interaction

HTGR
- Primary System
  - Deposition / Condensation
  - FP Release
  - Resuspension / Revaporization

SFR
- Primary System
  - Deposition / Condensation
  - FP Release
  - Bubble Transport
  - Condensation & Dissolution of Vapors
  - Entrainment & Dissolution of Aerosols

FHR
- Primary System
  - Deposition / Condensation
  - FP Release
  - Resuspension / Revaporization
  - Bubble Transport & Entrainment / RN Vaporization

MSR
- Primary System
  - Deposition / Condensation
  - FP Release
  - Resuspension / Revaporization
  - Bubble Transport & Entrainment / RN Vaporization
Current Efforts

• Finalize a new ORIGEN data transfer file

• MELCOR/MACCS needs
  - decay heat
  - activity
  - mass
  - time-dependence
  - potential re-nodalization, e.g. core/spent fuel pool assembly data grouped into coarse axial/radial distributions

• Perform basic demonstrations
Interface strategy

• Self-contained data set

• Transfer basic data (number of atoms, decay constant, Q-value) and reconstruct derived (decay heat)
  - Easy to audit/compare
  - Perform UQ

• Simple hierarchical format (JSON) with demonstration processing via python
Interface contents (1/2)

• data - nuclear data
  – Q-values
  – photon release fractions

• definitions
  – basic nuclide info
    • mass
    • atomic number
    • decay constant
    • energy level
  – nuclide vectors

• responses
  - currently only one "type"
Interface contents (2/2)

- each block has a "type" that defines the contents
- each type includes a "version" for backwards compatibility
- multiple responses can be included (BOC and EOC data here)
- zipped data can be 5 MB → binary HDF5 could have same structure
Summary

• SCALE has a major role in NRC Severe Accident Analysis for Advanced Reactors providing data to MELCOR/MACCS

• Uncertainty/sensitivity analysis will be important

• Current work streamlining communication through new interface file → intended to become new ORIGEN results packet (process with off-the-shelf python)