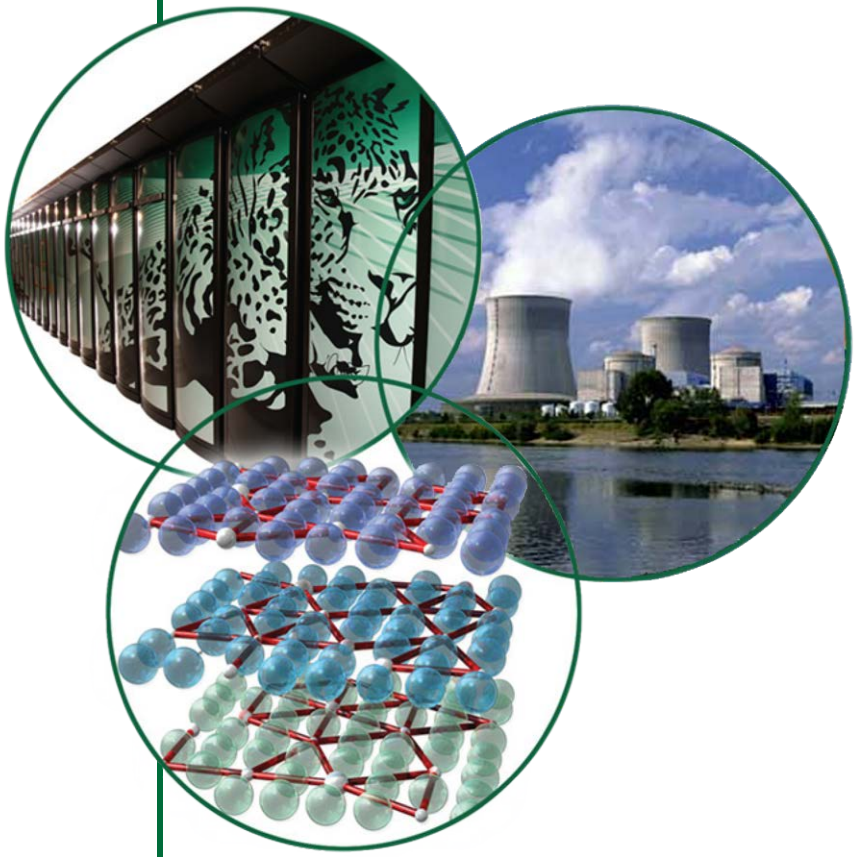
Model Development and Validation for FHR Licensing

Dr George Flanagan

Chinese Academy Visit

April 13, 2012



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Historically Testing Has Been Used to Develop the Safety Case for Licensing Since Models by Themselves Lack Precision or Need Verification

- This is still the case even for evolutionary designs such as iPWRs
  - Even using advanced modeling and simulation
- More so for new (revolutionary) designs such as FHR
- Examples (old and new)
  - Critical facilities
    - Chicago Pile -1 (CP-1) Self sustaining chain reaction
    - Zero Power Plutonium Reactor (ZPPR) to support FFTF, CRBR
  - Hydraulic Test Loops
    - LOFT/Semi-scale to validate the performance of ECCS during a LOCA
    - B&W/mPOWER Integrated Test Facility (support mPOWER design and safety performance)
  - Test/Prototype/Demonstration reactors
    - Shippingport (PWR)
    - MSRE
    - EBR 1, EBR 2, FFTF,SEFOR

Testing/Experiments Can Be Used In A Number of Ways to Enhance Models

- Develop raw data to go into model
  - Cross sections (nuclear)
  - Crud buildup (water chemistry)
  - Material properties (structural)
- Develop correlations to support model
  - CHF correlations
  - Pebble abrasion/erosion
  - Pipe erosion
  - Materials irradiation

Testing/Experiments Can Be Used In A Number of Ways to Enhance Models (continued)

- Integral Benchmarks to validate models
  - Critical experiments
  - Hydraulic loops (real or simulant materials)
  - Full scale demonstration facilities (real plant data)

U.S. NRC Requires An Evaluation Model to Determine if the Analysis is in Compliance With Applicable Regulations (6 Basic Elements) RG 1.203

- Determine requirements for the evaluation model
- Develop an assessment base consistent with the determined requirements
- Develop the evaluation model
- Assess the adequacy of the evaluation model
- Follow an appropriate quality assurance protocol during the evaluation model development and assessment process (EMDAP)
- Provide comprehensive, accurate, up-to-date documentation

Evaluated Model Development Assessment Process Flow Chart

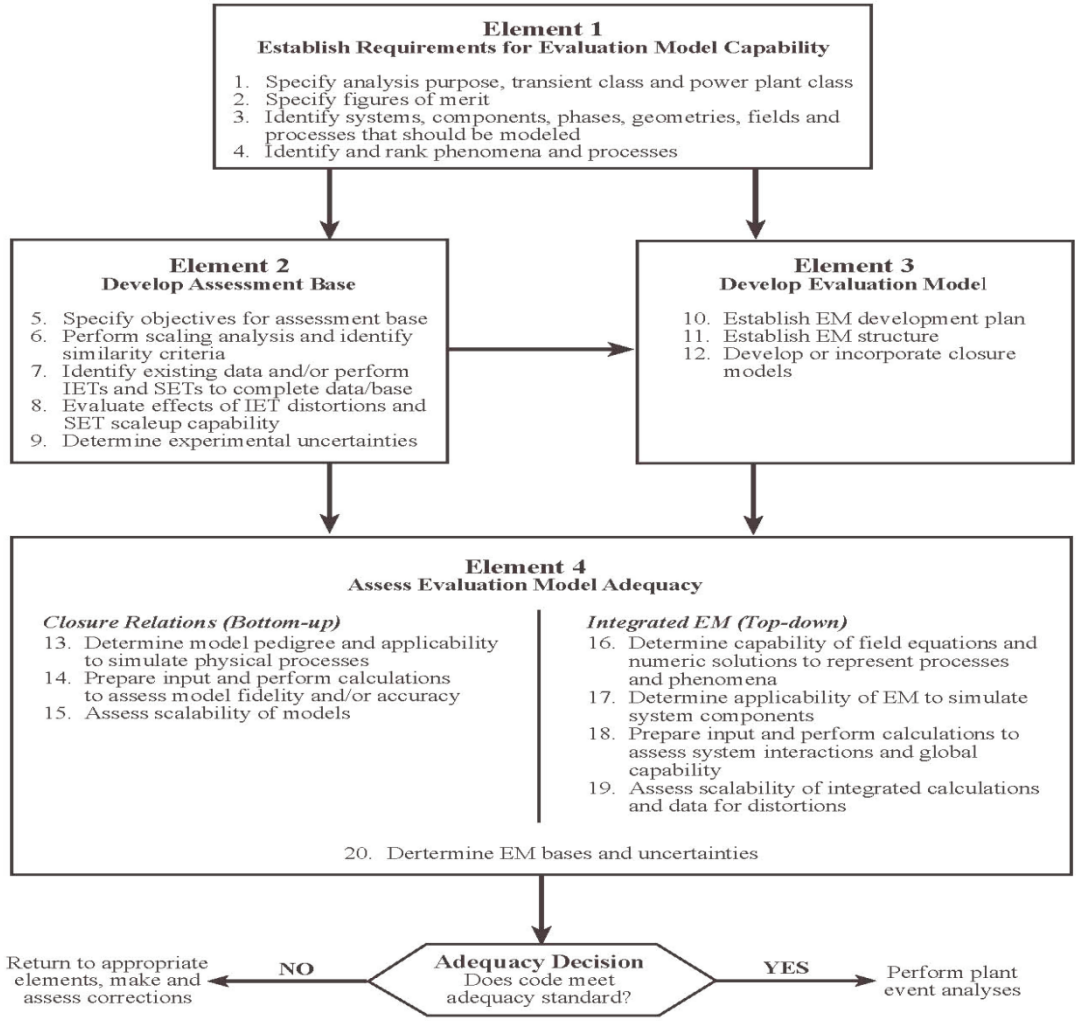


Figure 1. Elements of Evaluation Model Development and Assessment Process (EMDAP)

Develop an Assessment Base Consistent with the Determined Requirements

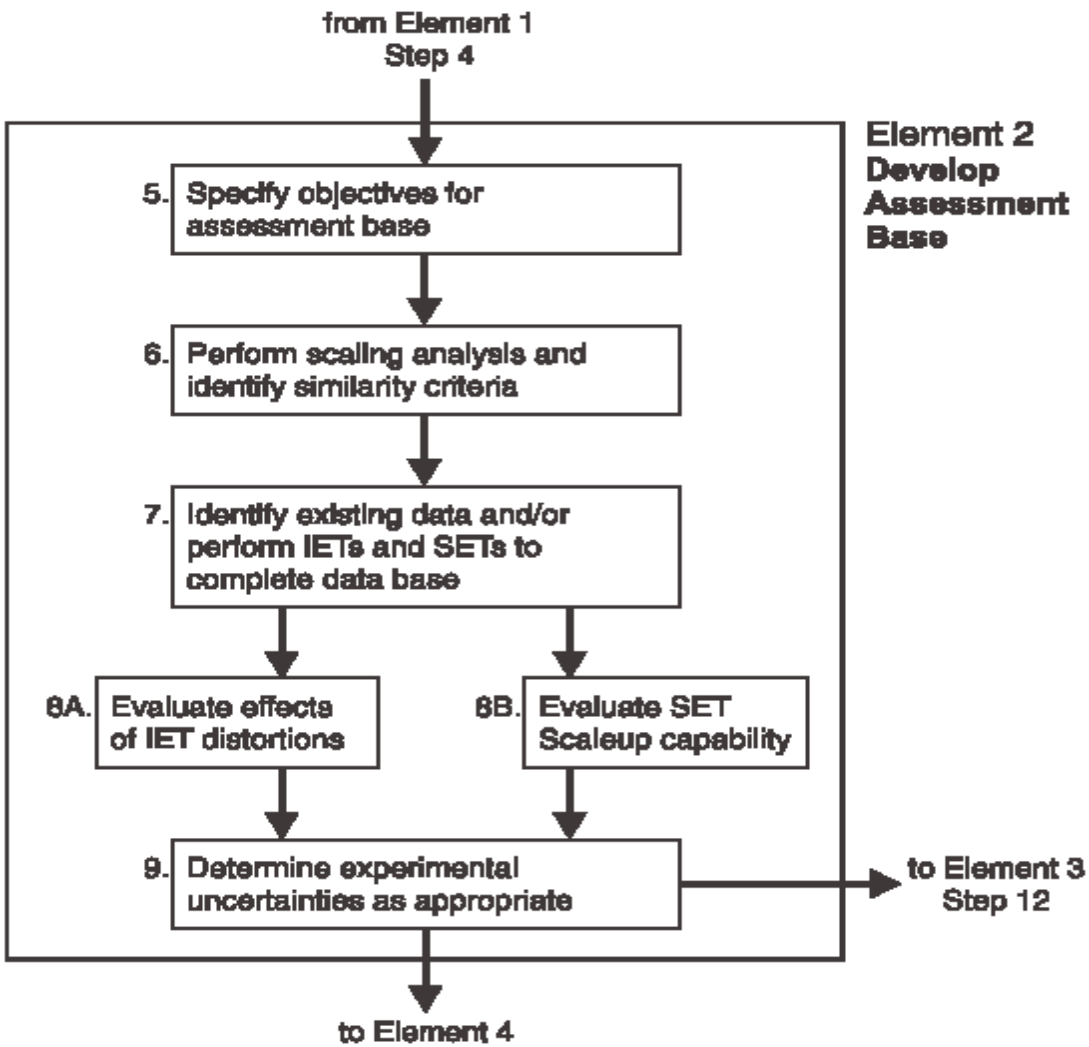


Figure 3. Steps in Element 2

Specify Objectives for Assessment Base

- The selection of the database is a direct result of the requirements established in Element 1
  - Separate effects experiments needed to develop and assess empirical correlations and other closure models
  - Integral systems tests to assess system interactions and global code capability
  - Benchmarks with other codes (optional)
  - Plant transient data (if available)
  - Simple test problems to illustrate fundamental calculational device capability

Scaling Analysis and Identify Similarity Criteria

- Scaling analyses should be conducted to ensure that the data, and the models based on those data, will be applicable to the full-scale analysis of the plant transient
  - Top Down: evaluates the global system behavior and systems interactions from integral test facilities
  - Bottom Up: address issues raised in the plant- and transient-specific PIRT related to localized behavior
- For those applications with a large number of processes and parameters, it is difficult to design test facilities that preserve total similitude between the experiment and the plant
- Based on the important phenomena and processes identified in Step 4 (PIRT) and the scaling analysis, the optimum similarity criteria should be identified
- The associated scaling rationales should be developed for selecting existing data or designing and operating experimental facilities

Identify Existing Data and/or Perform Integral Effects Tests (IETs) and Separate Effects Tests (SETs) To Complete the Database

- PIRT developed in Element 1—Step 4 is used to select experiments and data that best address the important phenomena and components
- A range of tests should be employed to demonstrate that the calculational device or phenomenological model has not been tuned to a single test
- A correlation derived from a particular data set may be identified for inclusion
  - An effort should be made to obtain additional data sets that may be used to assess the correlation

Evaluate Effects of IET Distortions and SET Scaleup Capability

- IET Distortions
  - Distortions in the integral effects test (IET) database may arise
    - From scaling compromises (missing or atypical phenomena) in subscale facilities
    - Atypical initial and boundary conditions in all facilities
- SET Scaleup Capability
  - Correlations should be based on separate effects tests (SETs) at various scales

Determine Experimental Uncertainties As Appropriate

Uncertainties arise from

- Measurement errors
- Experimental distortions
- Other aspects of experimentation

- If the quantified experimental uncertainties are too large compared to the requirements for evaluation model assessment
  - The particular data set or correlation should be rejected

FHR is A Totally New Design and Will Require Significant Effort Before Presenting A Safety Case to the Regulator

- Design requirements similar to General Design Criteria need to be identified
- Phenomena needs to be identified and ranked (PIRT)
- Models need to be identified and/or developed for analysis of transients/accidents phenomena
- Need to begin to develop tests needed to address the phenomena identified
  - Separate effects (using simulants and actual materials)
  - Possible integral tests