



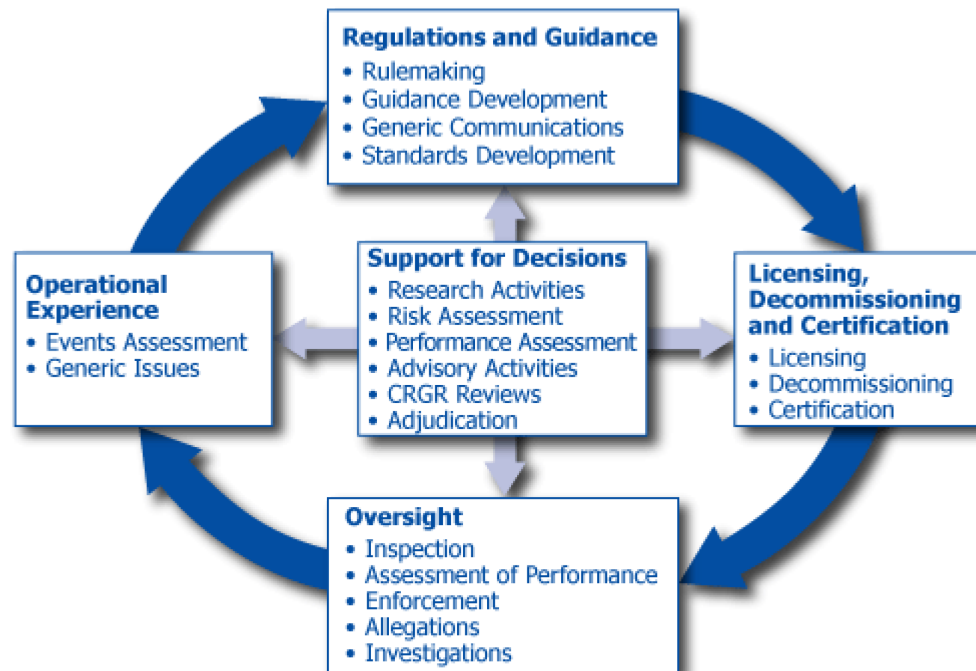
Software Verification and Validation: Examples from the Safety Arena

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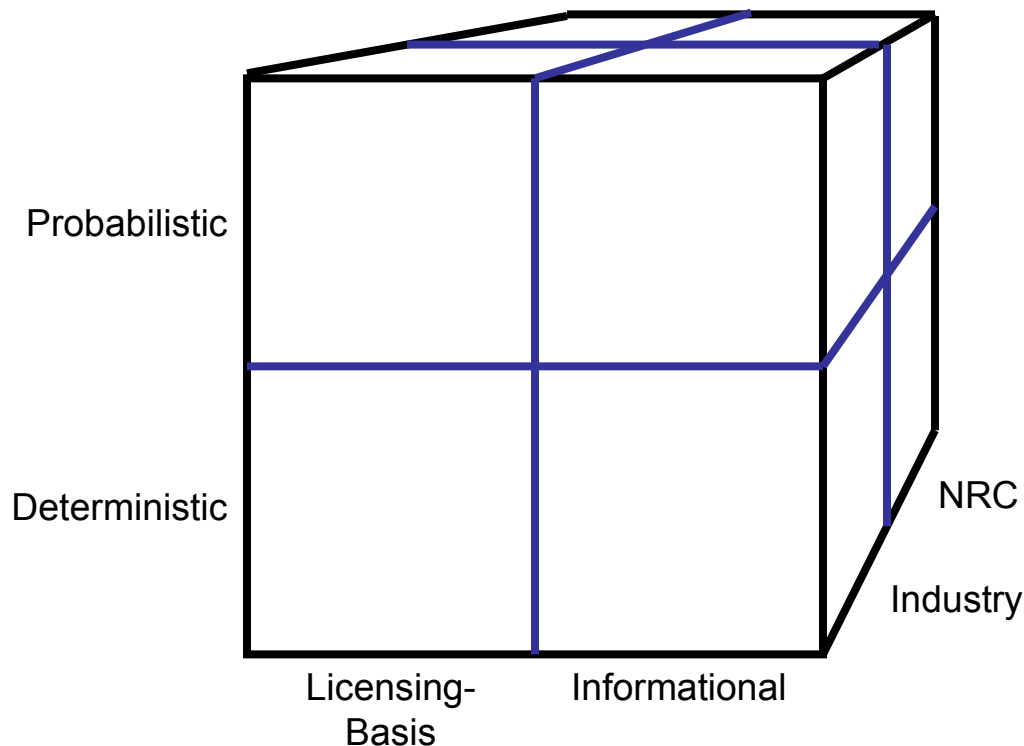
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research

Presented at
INMM Workshop on VA Tools
Boston, MA; September 14-16, 2015

Wide Variety of Code Uses



Setting the Scene: Terminology



Verification

Does the program do what it's required to do?

- Life cycle reviews and audits
- Peer inspections
- Informal tests

Validation

Are the results accurate?

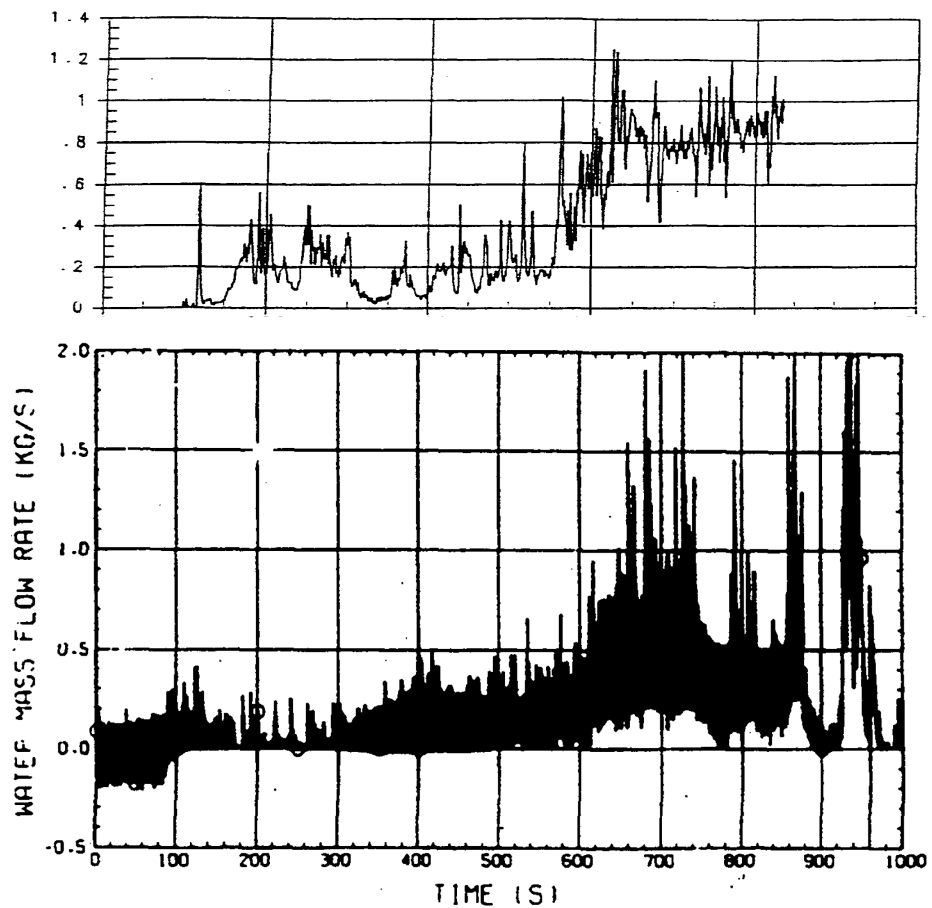
- Tests

Evaluation Technology = {methods, *models*, *tools*, data}

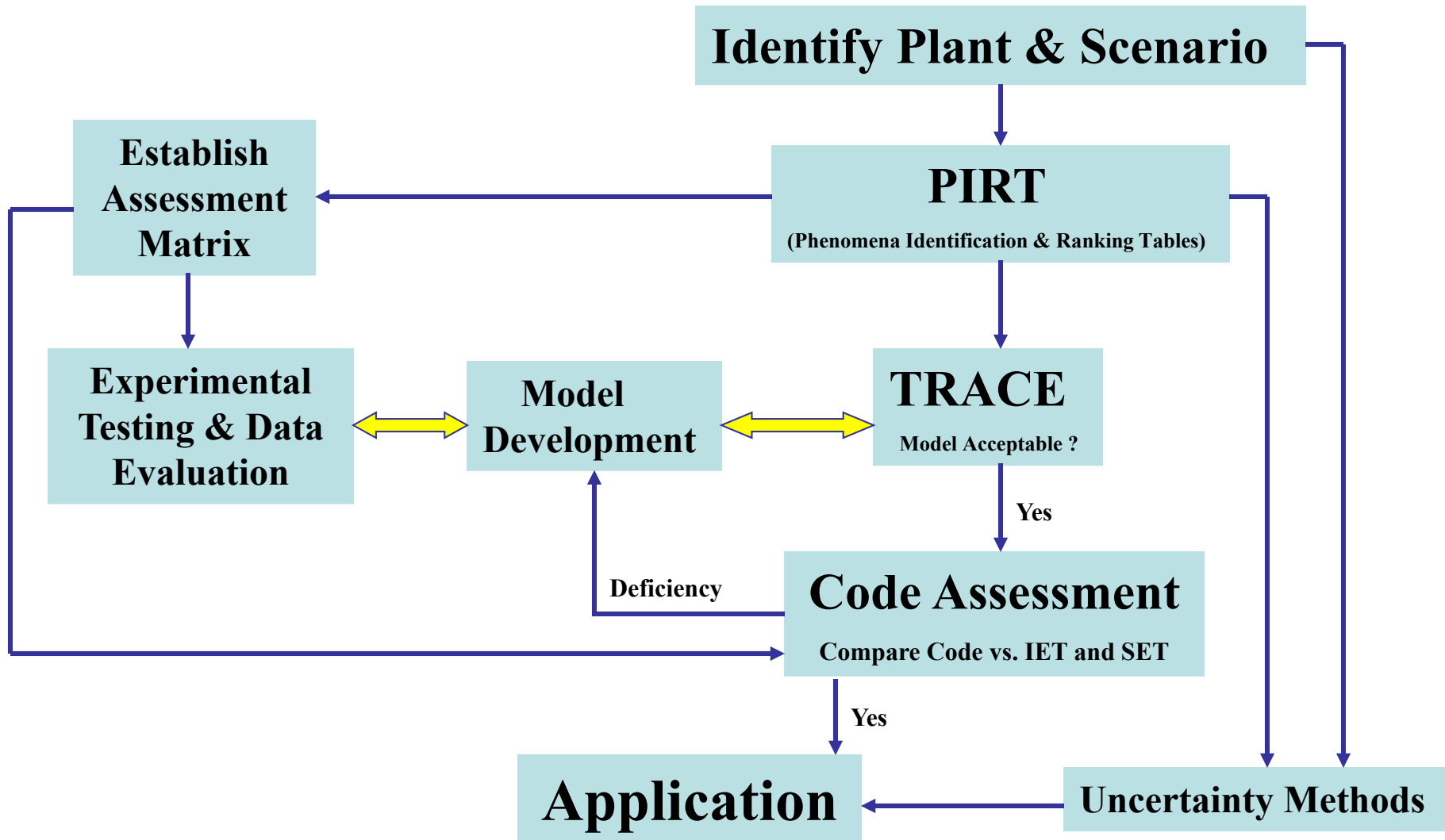
T-H Codes for Licensing

- Deterministic thermal-hydraulics analysis codes to perform/confirm required Design Basis Accident (DBA) analyses
- Validation/Assessment: Code Scaling, Applicability and Uncertainty (CSAU) – NUREG/CR-5249
 - Objective: determine code accuracy, biases, and shortcomings
 - Fundamental problems (basic phenomena), separate effects tests, integral effects tests
- Staff Evaluation Report (SER) specific to design and scenario, e.g.,
“...with the limitations and conditions described in this report, the staff concludes that the NOTRUMP code has been appropriately modified to include the features necessary to model the AP600 plant and the phenomena expected during an AP600 SBLOCA.” (NUREG-1512)
- Evaluation generally compares predictions with experiments.
Considers whether:
 - Discrepancies are acceptable, or
 - Are conservative, or
 - Are unimportant

Code Prediction vs. Experiment



Code Development / Assessment



Example T-H Code SER Headings

- Phenomena Identification and Ranking
- Analytical Models
- Component Models
- Code Qualification
 - Benchmark Calculations
 - Separate Effects Tests
 - Integral Effects Tests
- Regulatory Compliance
- ACRS Review
- Resolution of Open and Confirmatory Items

Severe Accident (Beyond DBA) Codes

- Principal NRC code: MELCOR
- NRC applications include:
 - support regulatory decision making (e.g., rulemakings)
 - research studies (e.g., SOARCA: NUREG-1935)
 - PRAs (Level 3 PRA, success criteria confirmation)
- MELCOR Validation
 - Software Quality Assurance program meeting requirements of NUREG/BR-0167
 - Best modeling practices: NUREG/CR-7008
 - Independent review
 - Comparison against analytical solutions, separate effects tests, integral tests, actual accident data

PRA Code: SAPHIRE (Systems Analysis Programs for Hands-on Integrated Reliability Evaluations)

- NRC applications include:
 - Standardized Plant Analysis Risk (SPAR) model development and use
 - Ongoing Level 3 PRA project
- SAPHIRE Validation
 - Software Quality Assurance program meeting requirements of NUREG/BR-0167
 - Acceptance tests against known results
 - Feedback from users

SPAR Models

- NRC applications include:
 - Reactor oversight
 - System and component studies
 - Generic issue screening
- SPAR model validation
 - Software Quality Assurance program (NUREG/BR-0167)
 - Modeling guidance (e.g., Risk Assessment of Operational Events handbook)
 - Reviews (internal, onsite visits, external peer)
 - Comparisons (test cases, licensee model, sister plant models)
- PRA model validation challenges
 - Probabilistic outcomes and importance of “tail-end” events
 - Data
 - “Non-exchangeable” events at other facilities
 - Meaningfulness of intermediate end state estimates

Concluding Remarks

- Models \neq Model-Building Tools
- V&V/evaluation approach considerations include:
 - Intended regulatory application and use of code-generated information in application
 - Fundamental character of output (probabilistic vs. deterministic, importance of “tails”)
 - Documented modeling best practices
 - Data for comparisons (for different “scales”)
 - Need for/role of NRC independent codes
- Staff acceptance can be highly specific (e.g., design, scenario, purpose)
- Expert input is critical
 - Identification and prioritization of key issues
 - Assessment of results

Backup Slides

Formal Terminology (NUREG/BR-0167*)

- Verification

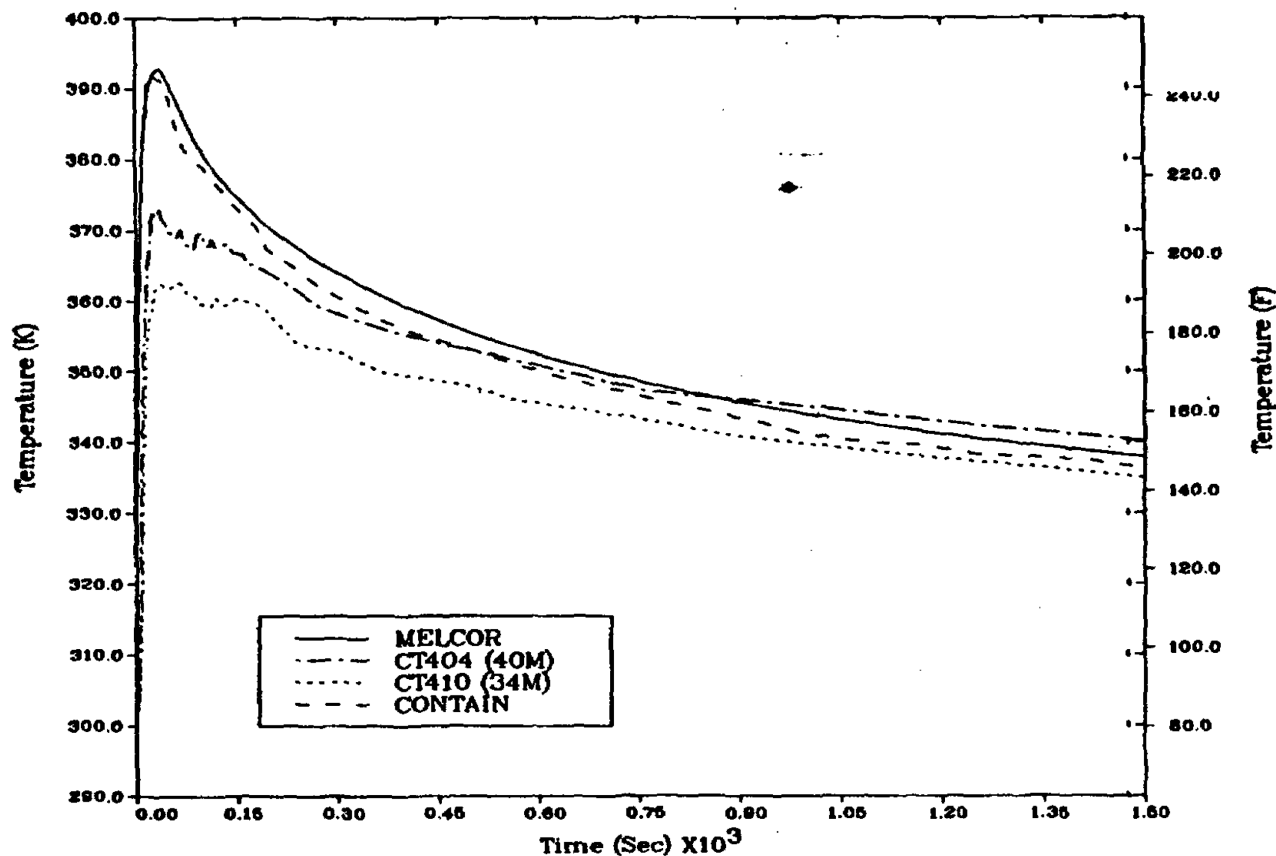
“[T]he process of ensuring that the products and processes of each major activity of the life cycle meet the standards for the products and the objectives of that major activity.”

- Validation

“[T]he process of demonstrating that the as-built software meets its requirements.”

*Software Quality Assurance Program and Guidelines,” NUREG/BR-0167, 1993.

Example: MELCOR Comparison



SPAR Model QA Process

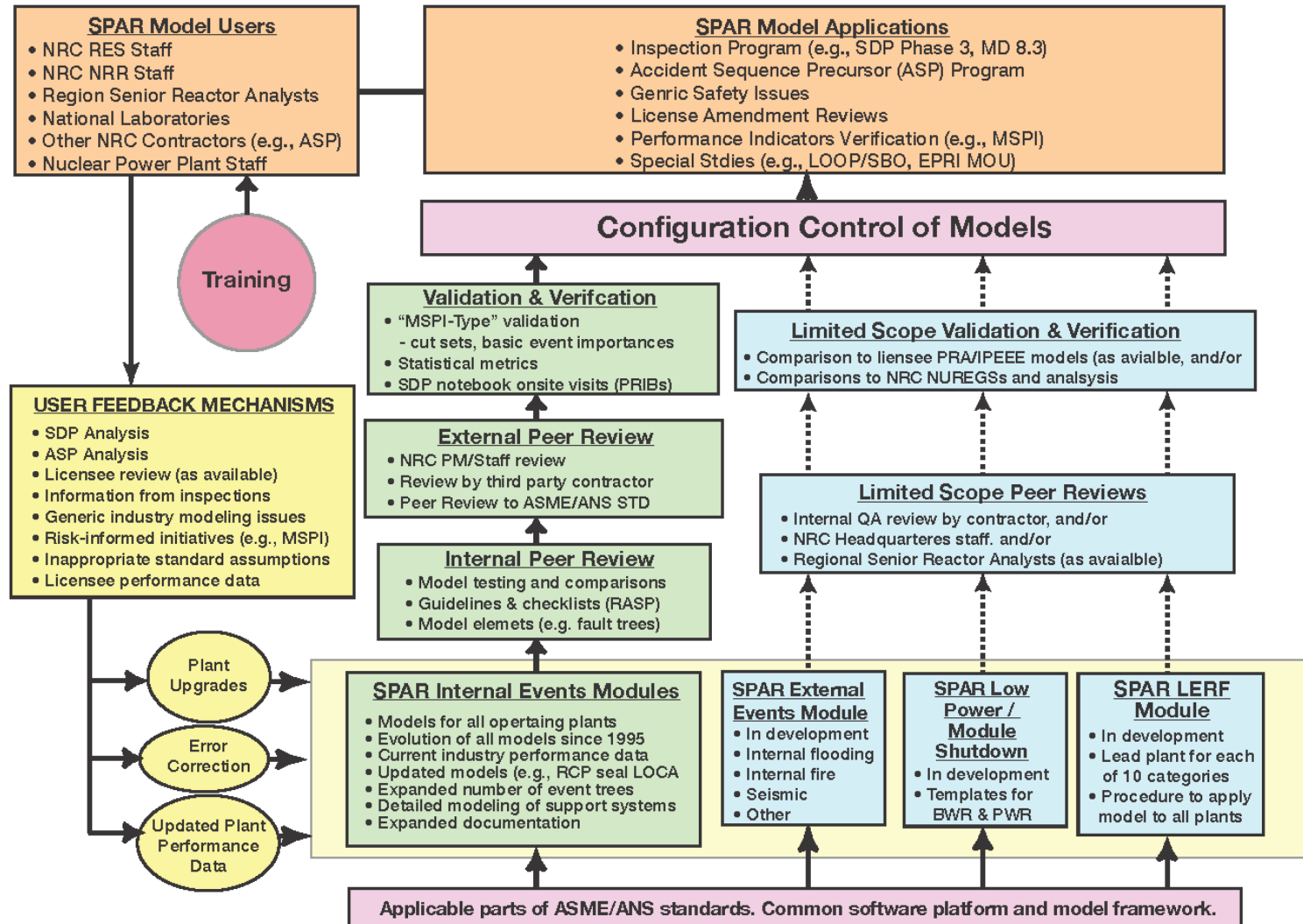


Figure from "United States Nuclear Regulatory Commission Standardized Plant Analysis Risk (SPAR) Model Quality Assurance Plan, Rev. 1," June 19, 2013. (ADAMS ML13141A333)

On “Best-Estimate” Calculations

- Regulatory Guide 1.157, “Best-Estimate Calculations of Emergency Core Cooling System Performance,” May 1989.
Lists acceptable models, correlations, data, and model evaluation procedures
- ***Philosophy***
“A best-estimate calculation uses modeling that attempts to realistically describe the physical processes occurring in a nuclear reactor. There is no unique approach to the extremely complex modeling of these processes.”
- ***Allowance for biases/simplifications***
“The introduction of conservative bias or simplification in otherwise best-estimate codes should not ... result in calculations that are unrealistic, that do not include important phenomena, or that contain bias and uncertainty that cannot be bounded. Therefore, any calculational procedure ... should be compared with applicable experimental data ...”
- ***Data sources***
“Reference 7 ... provides a summary of the large experimental data base available, upon which best-estimate models may be based. While inclusion in Reference 7 does not guarantee that the data or model will be acceptable, the report describes and references a large body of data generally applicable to best-estimate models.”