CAREM and Differences from CSAU

- Objective
- Overview of CAREM
- Descriptions for each step
- Conclusion

CAREM : Code Accuracy based Realistic Evaluation Model (APR1400-F-A-TR-12004-NP, Rev.0); ML13023A080

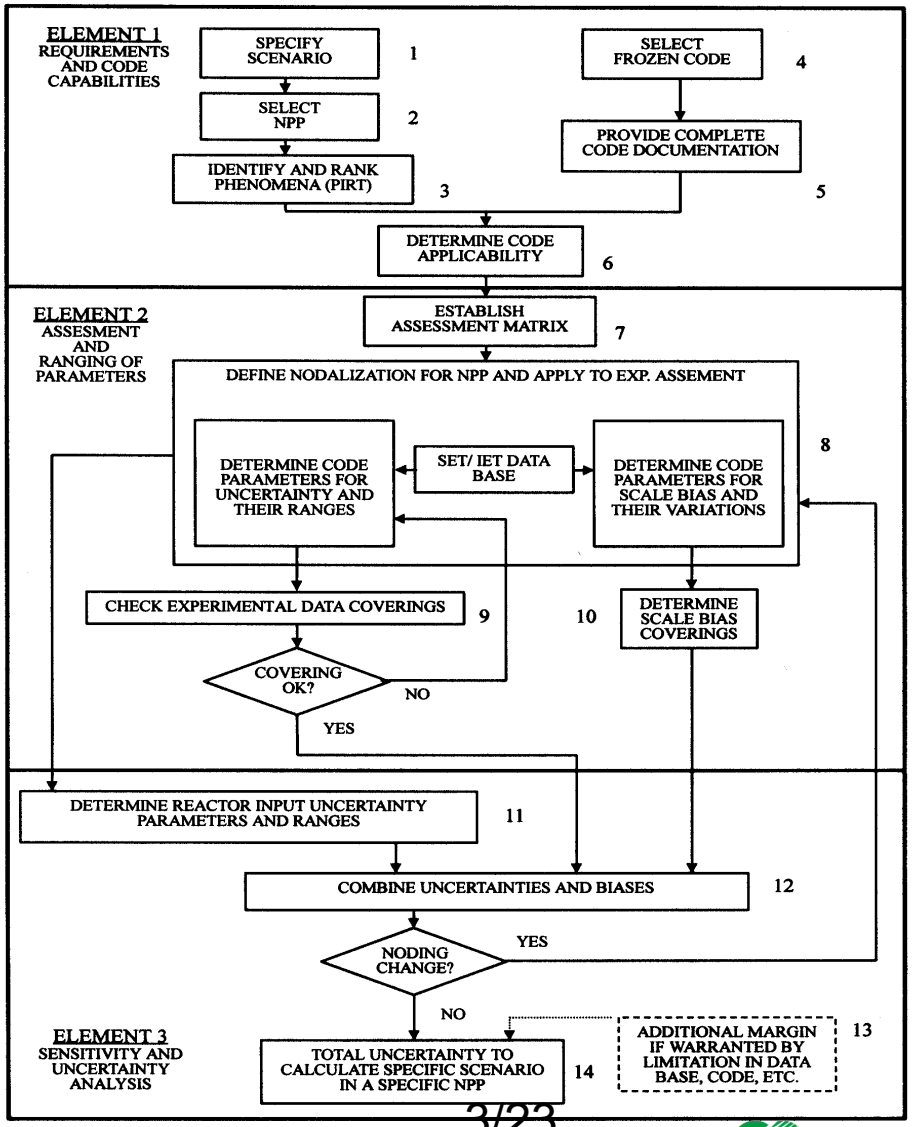
Objective

- To provide a summary of the APR1400 LBLOCA Realistic Evaluation Model (CAREM) Topical Report
- To provide the differences from the CSAU

CSAU : Code Scaling, Applicability and Uncertainty (NUREG/CR-5249)

Overview of CAREM (1/2)

- CAREM consists of 3 elements and 14 steps as in CSAU.
- Step 9 checks Experimental Data Covering (EDC) using the uncertainty parameters determined in step 8. If it fails, step 8 repeats until the covering is satisfied.
- Non-parametric statistics and Simple Random Sampling (SRS) calculation are used in EDC as well as in plant calculations for propagation of uncertainties.



Overview of CAREM (2/2)

Best Estimate + Uncertainty Quantification

1. CAREM developed based on the CSAU

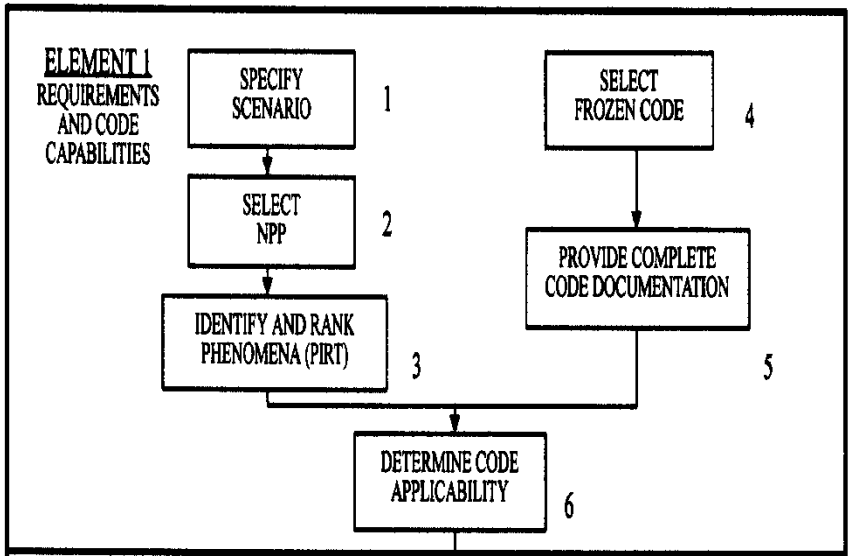
   - Uncertainties are quantified by non-parametric statistics and SRS calculation

   - Introduce EDC for confirmation of uncertainty parameters and their ranges & distributions

2. RELAP5/MOD3.3 + CONTEMPT4/MOD5

   - Two codes exchange mass & energy (RELAP) and pressure (CONTEMPT) as boundary conditions for each other

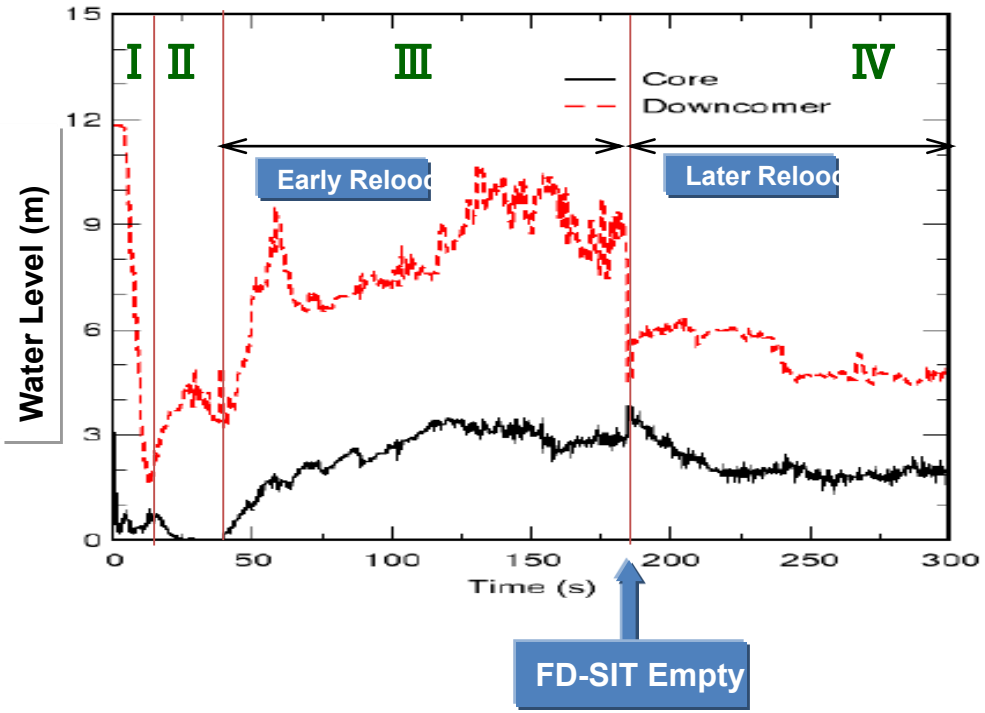
Element 1
Requirement and Code Capabilities



- **The same as CSAU**

Step 1 : Specify Scenario

- **Scenario** : [ ] TS



I : Blowdown (~ 20 sec)

break open ~ initiation of SIT-FD

II : Refill (~ 35 sec)

until mixture water level is reached to the bottom of active core

III : Early Reflood (~ 190 sec)

until SIT-FD empty

IV : Later Reflood

after SIT-FD empty

Step 2 : Select NPP

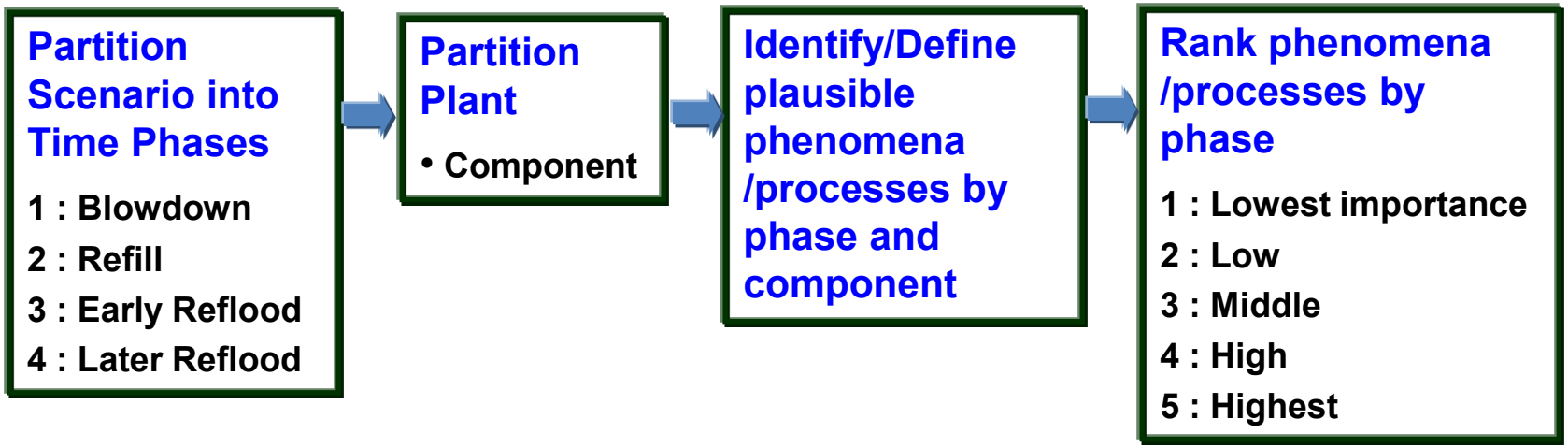
➢ APR1400

Step 3 : Identify and Rank Phenomena (PIRT)

➢ APR1400 LBLOCA PIRT was developed based on KNGR PIRT

- INEEL/KINS developed KNGR PIRT (2001)
- Panel had ~150 MY collective experiences

➢ Findings from various tests and code calculations were reflected



Step 3 : PIRT

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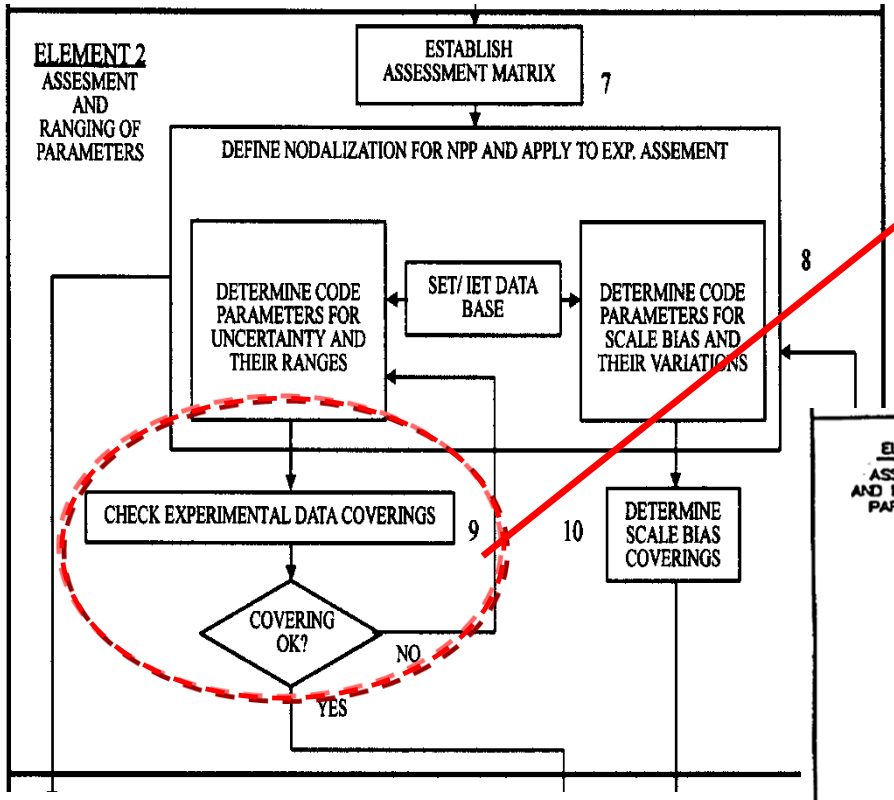
Step 4 : Select Frozen Code

- RELAP5/MOD3.3/K & CONTEMPT4/MOD5

Step 5 : Provide Complete Code Documentation

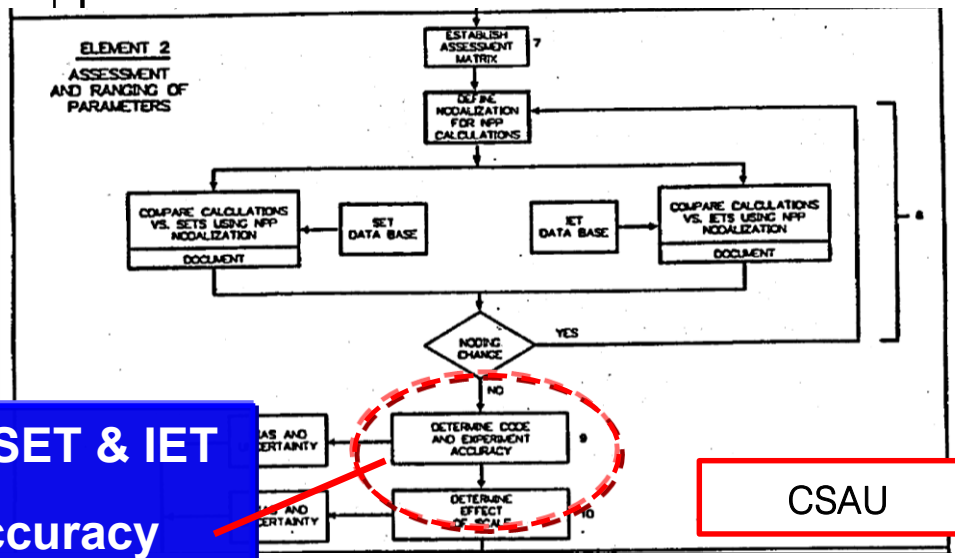
Step 6 : Determine Code Applicability

Element 2
Assessment and Ranging of Parameters



Unique Step

to determine code-accuracy-based uncertainty parameters and their ranges.



To evaluate overall code accuracy for SET & IET

: Definition of code and experiment accuracy

CSAU

Step 7 : Establish Assessment Matrix

- **Assessment Matrix**

  - Includes various SETs, IETs and tests for APR1400
    - to confirm code's predictability of LBLOCA phenomena
    - to assess code accuracy
    - to confirm code's scale-up capability
    - to determine noding
    - to range uncertainty parameters
  - Includes developmental assessments as well
  - APR1400 related tests (conducted by KAERI)

    - Reference file location: '#4 Reference\#2 Topical reference'

    ■ MIDAS : ECC bypass - Appendix F

    ■ DOBO : Downcomer boiling – Appendix G

    ■ ATLAS : Overall reflood phenomena, ECC bypass, DC boiling – Appendix E

    ■ VAPER : SIT-FD – Appendix H

    ※ MIDAS, DOBO, VAPER : SET Facility

    ATLAS : IET Facility

Step 8 : Define Nodalization for NPP and Apply to Exp. Assessment

- **Determine Nodalization for NPP (Step 8.1)**
  - Guide lines and the various nodalizations of NPP & test facilities in RELAP5 documents and international experiences were referenced.
  - NPP nodalization is kept in the test facility nodalization.

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Determine Code Parameters and their Ranges (Step 8.2)

(Plant operation related parameters are covered in Step 11)

- Candidate uncertainty parameters are first determined by comparing the important phenomena and corresponding code models, and by performing the auxiliary calculations.
- The ranges of candidate parameters are validated as a set by way of Experimental Data Covering (EDC) against SET and IET data.

Code Parameters

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Code Parameters for Scale Bias and their Variations (Step 8.3)

NUREG/CR-5249 (CSAU)

- Main components that cause code bias in NPP calculation are DC, LP, and UP which are distorted in a power-to-volume scaled facility.
- ECC bypass and liquid carry-over to SGs (steam binding) are affected.

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Step 9 : Check Experimental Data Coverings

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CAREM: Code accuracy (Step 9.1)

- This step designed to evaluate overall code accuracy using assessment results of experiments.

CSAU: Definition of code and experimental accuracy (Step 9)

- This step is the same with step 9.1 of the CAREM.

Step 9 : Check Experimental Data Coverings

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➢ CAREM: Experimental Data Covering (Step 9.2)

- Experiment data covering was introduced to check whether selected uncertainty parameters and their ranges could cover experiment data.
- If it fails, Step 8 repeats until the covering is satisfied.

Step 10 : Determine scale bias coverings

- Based on the code assessments in Step 8, following bias calculations are determined

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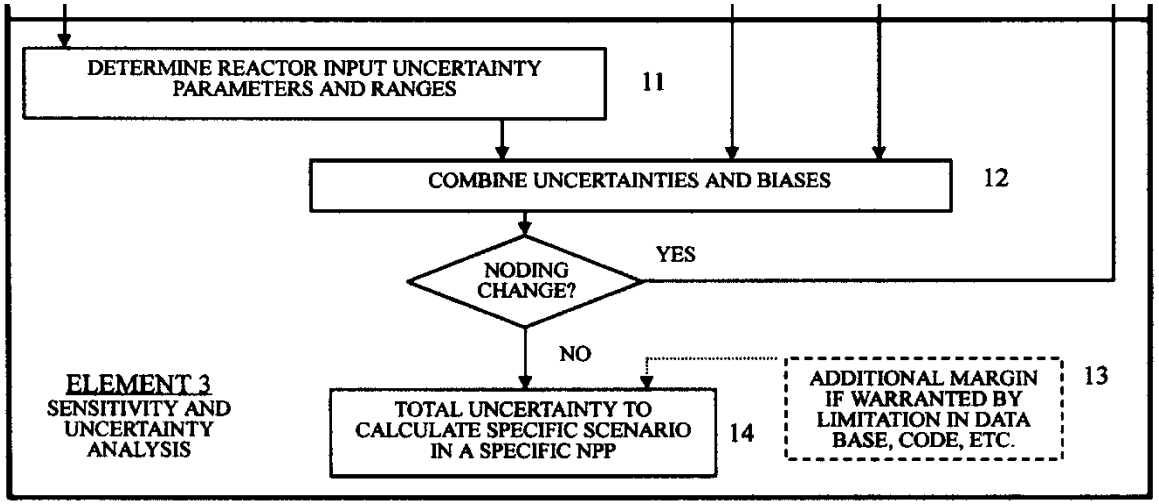
- Bias calculation of NPP are evaluated in Step 12.

Element 3
Sensitivity and Uncertainty Analysis



- Addresses important plant specific parameters (Step 11)
- Reactor input uncertainty parameters and code uncertainty parameters are taken into the NPP SRS calculations (Step 12)
- Scale bias are added to 95/95 values (Step 12)
- Additional uncertainties are added (Step 13 & 14)

❖ CSAU has the same analysis processes except uncertainty quantification method

Step 11 : Determine reactor input uncertainty parameters and their ranges

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Step 12 : Combine Uncertainties and Biases

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Step 12 : Combine Uncertainties and Biases

- CAREM adopted non-parametric statistics and SRS calculation to quantify uncertainty propagation

- Whereas, response surface method is used in CSAU

Non-Parametric Statistics

- Monte Carlo calculations : Simple Random Sampling (SRS) Calculation
- Number of calculations – Wilks formula
  - 59 cases : $1 - (p)n \geq q$ (1st highest value calculated is 95/95)
  - 124 cases : $q = 1 - [p^n + n(1-p)p^{n-1} + 1/2*n(n-1)(1-p)^2p^{n-2}]$

    (3rd highest value calculated is 95/95)

    where, $p = 0.95$, $q = 0.95$

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Step 13 : Additional Uncertainty

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Step 14 : Total Uncertainty

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Conclusions

- CAREM has been developed based on the CSAU

- Main differences between CAREM and CSAU
  - Uncertainty parameters and their ranges are confirmed by experiment data cover (Step 9.2)
    → Code accuracy which is step 9 of the CSAU is evaluated in Step 9.1

  - CAREM adopted SRS calculation based on non-parametric statistics instead of response surface which is used in CSAU (Step 12)

Thank you for your attention