Passive system Evaluation by using Integral thermal-hydraulic test facility

#537, **Rui-Chang Zhao, SNPTRD**

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PSAM12 ***International Conference***

- Briefly introduction of SNPTRD
- Engineered safety system & Ongoing T-H test research
- Evaluation by integral T-H test

Briefly introduction of SNPTRD

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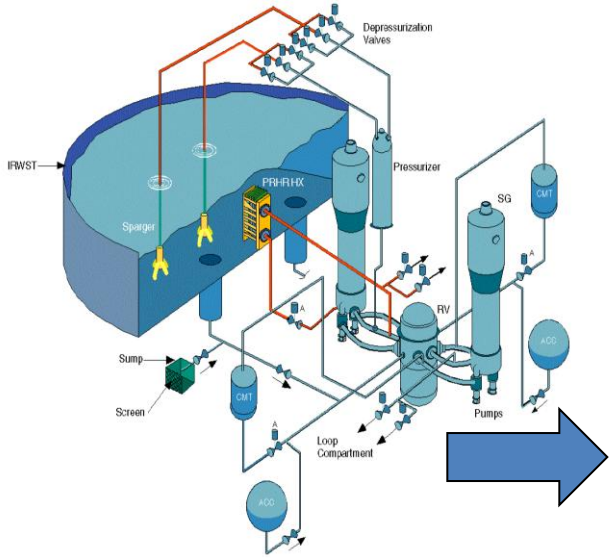
- SNPTRD (State Nuclear Power Technology R&D Center) was founded in 2008, a platform for advanced research of AP1000, CAP1400
- Founded by industry leader SNPTC (65%) and research pioneer Tsinghua University (35%)
- A national nuclear R&D center in China
  - Passive Core Cooling System (PXS) research
  - Passive Containment Cooling System (PCCS) research
  - Severe accident research
  - Nuclear safety research
  - Reactor physics research
  - Key equipment research

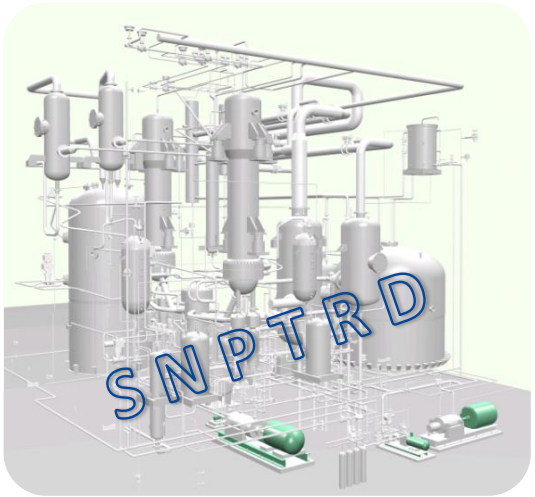
Engineered safety system & Ongoing T-H test research

Test Facilities for Engineered Safety System

Integral Effects Test (IET)

of CAP1400 Large Passive Plant





Passive core cooling system: (height scale 1/3)

ACME(Advanced Core-Cooling Mechanism Experiment)

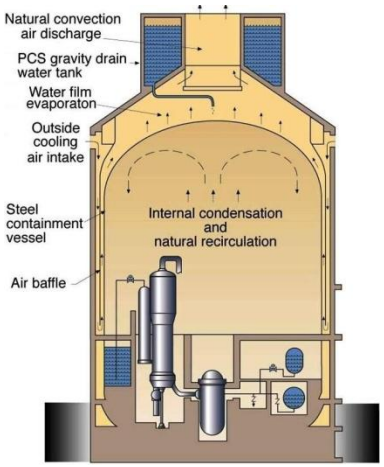
☐Role of ACME

- To simulate the operation of passive core cooling system of CAP1400 for SB-LOCA
- To validate the engineering design of the passive core cooling system
- To collect thermal-hydraulic data for safety code assessment

Test Facilities for Engineered Safety System

Integral Effects Test (IET)

of CAP1400 Large Passive Plant



Passive Containment Cooling System: (height scale 1/8)

CERT(Containment safety vErification via integRal Test)

☐Role of CERT

- To validate the applicability of WGOTHIC(safety code for containment assessment)
- To verify the engineering design of the passive containment cooling system
- To scaled-simulate the physical process in accident scenario, and the performance of passive containment cooling system of CAP1400

Test Facilities for Engineered Safety System

Separate Effects Tests (SETs)

of CAP1400 Large Passive Plant

- **In-Vessel Retention (IVR)** *related*:

  - Metal Layer Heat Transfer Experiment

  - Verify Globe-Dropkin
  - Relationship Obtain a proper correlation
  - Investigate the behavior of the coupled heat transfer in metal layer

  - Key Factors of Improving CHF Experiment

  - Investigate the key factors of CHF
  - Obtain the influence of chemical solution to CHF
  - Testify the effects of surface characteristic to CHF

Test Facilities for Engineered Safety System

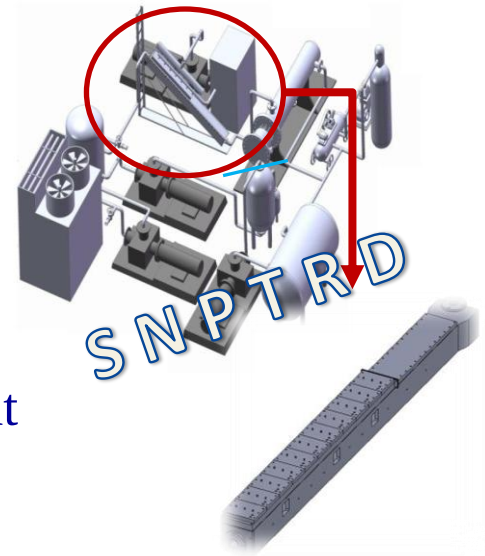
Separate Effects Tests (SETs)

of CAP1400 Large Passive Plant

- **PCCS** *related:*
  - WAter Distribution Experiment facility (WADE)

- Study water cover area rate with the flow rate
- The period of the establishment of stable water film from the top to the bottom
- The effect of weir design to the water film

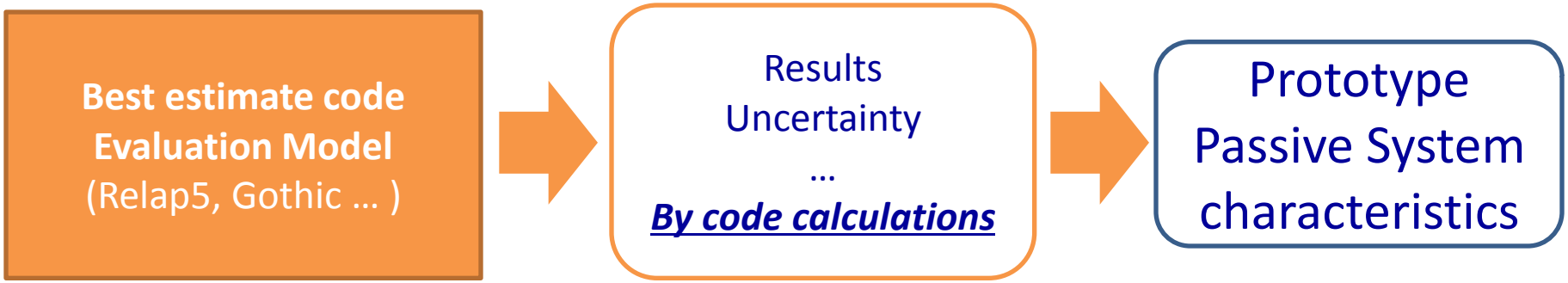
  - Steam Condensation o cOld Plate Experimen facility (SCOPE)
  - Inner Steam Condensation coupled Outer Evaporat ion experiment facility (ISCOE)



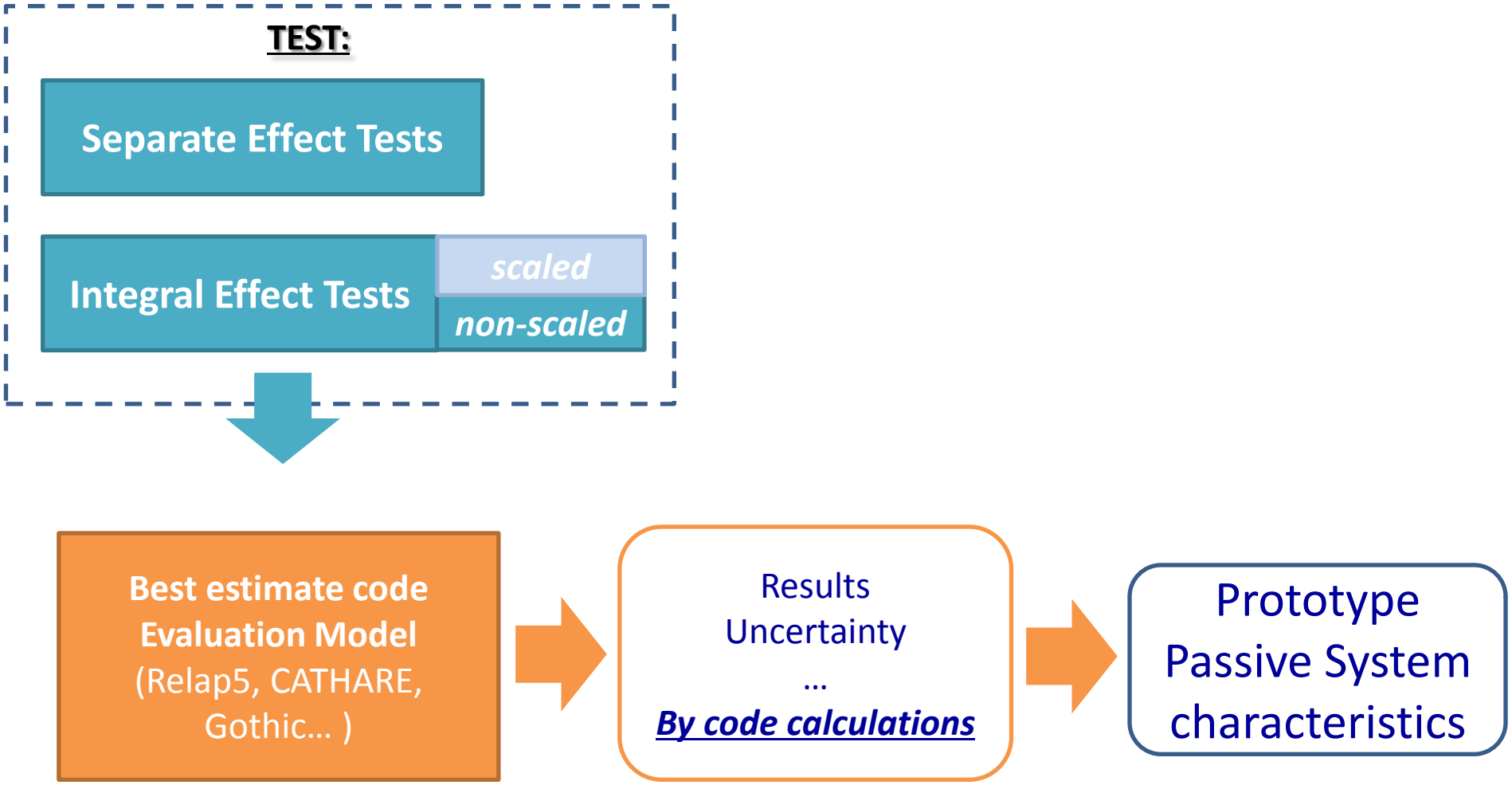
- To provide data on condensation heat and mass transfer in the presence of a non-condensable gas
- To valid the correlation of heat and mass transfer of condensation, which used in the assessment model

Evaluation by integral T-H test

Passive system evaluation process



Passive system evaluation process



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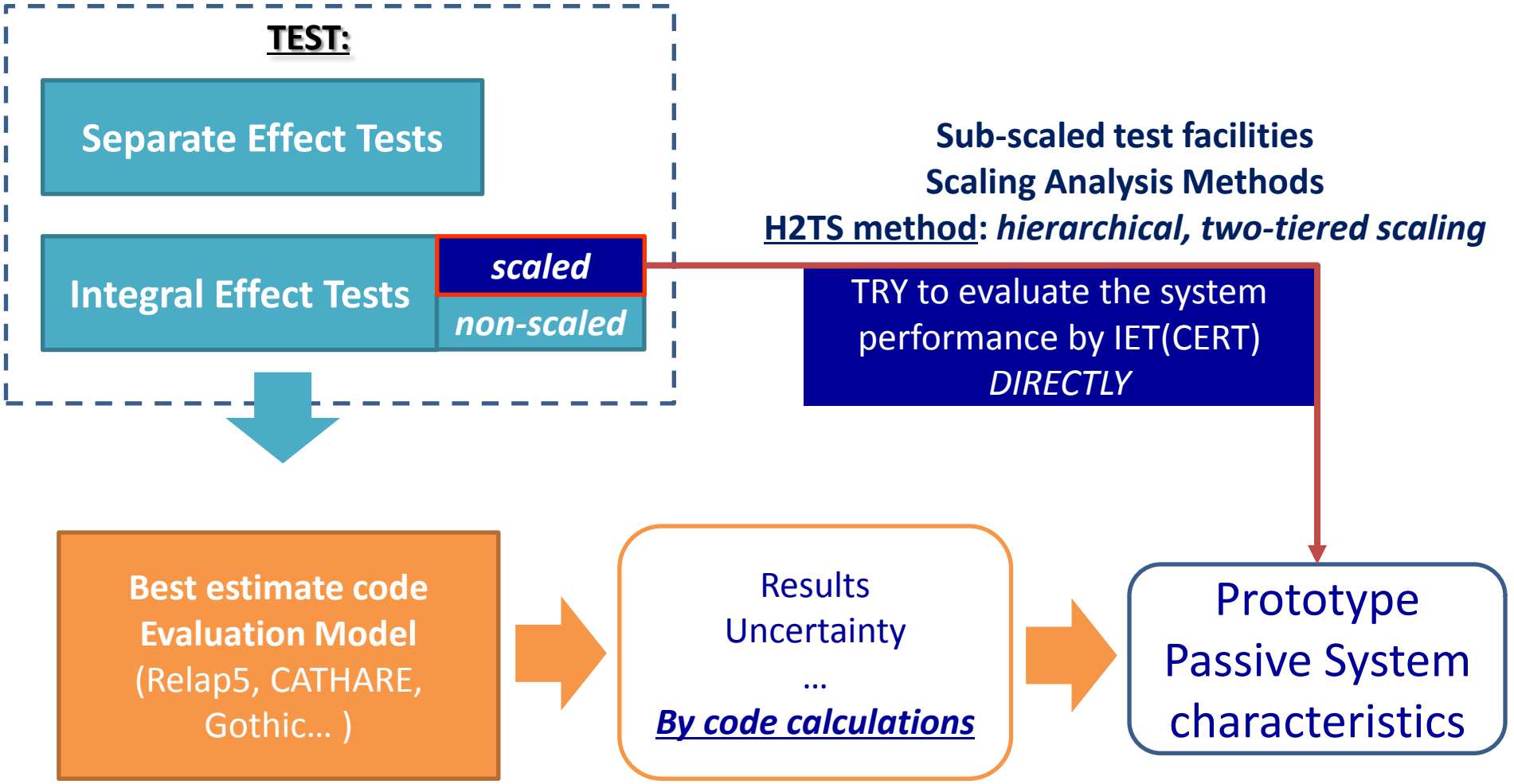
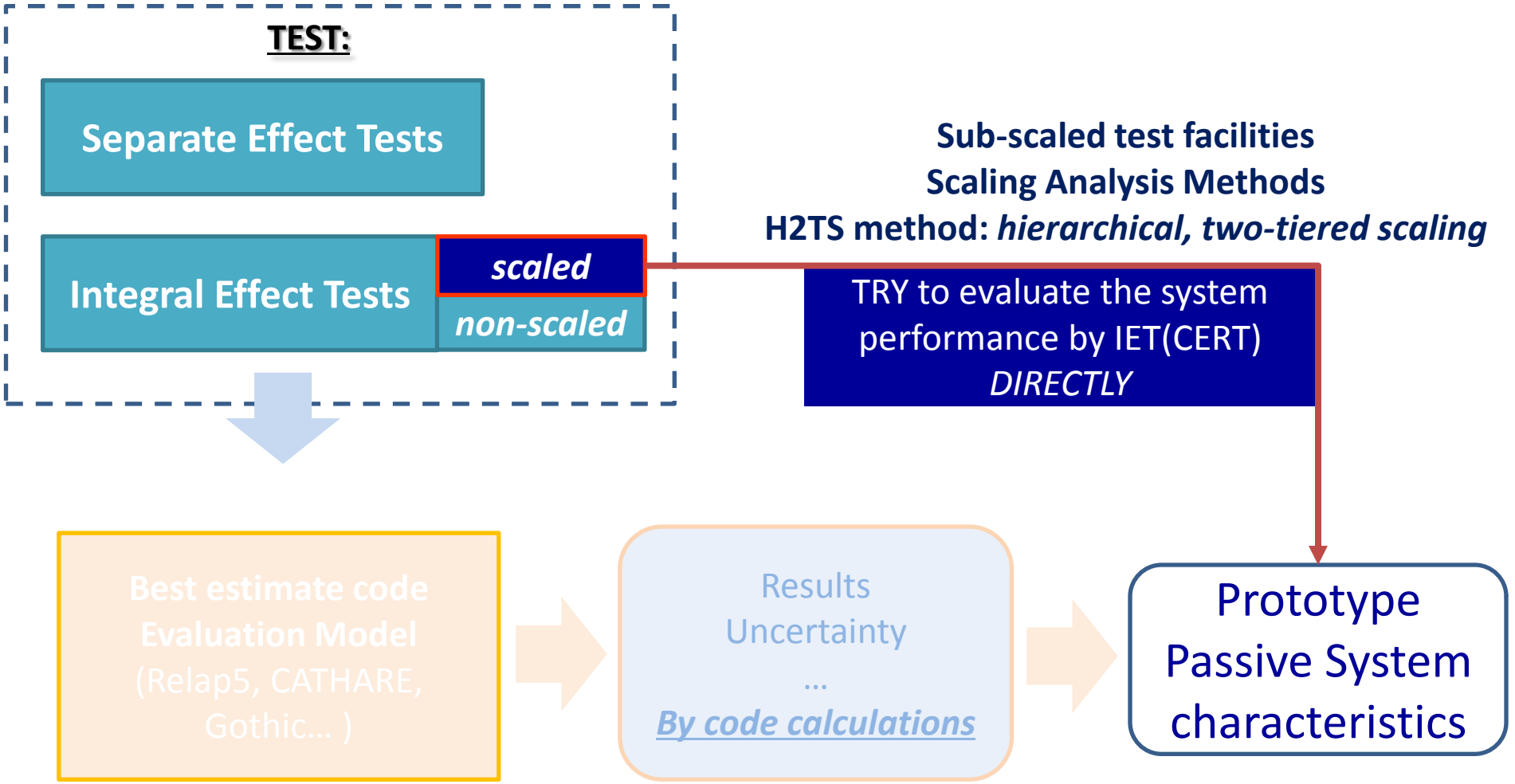
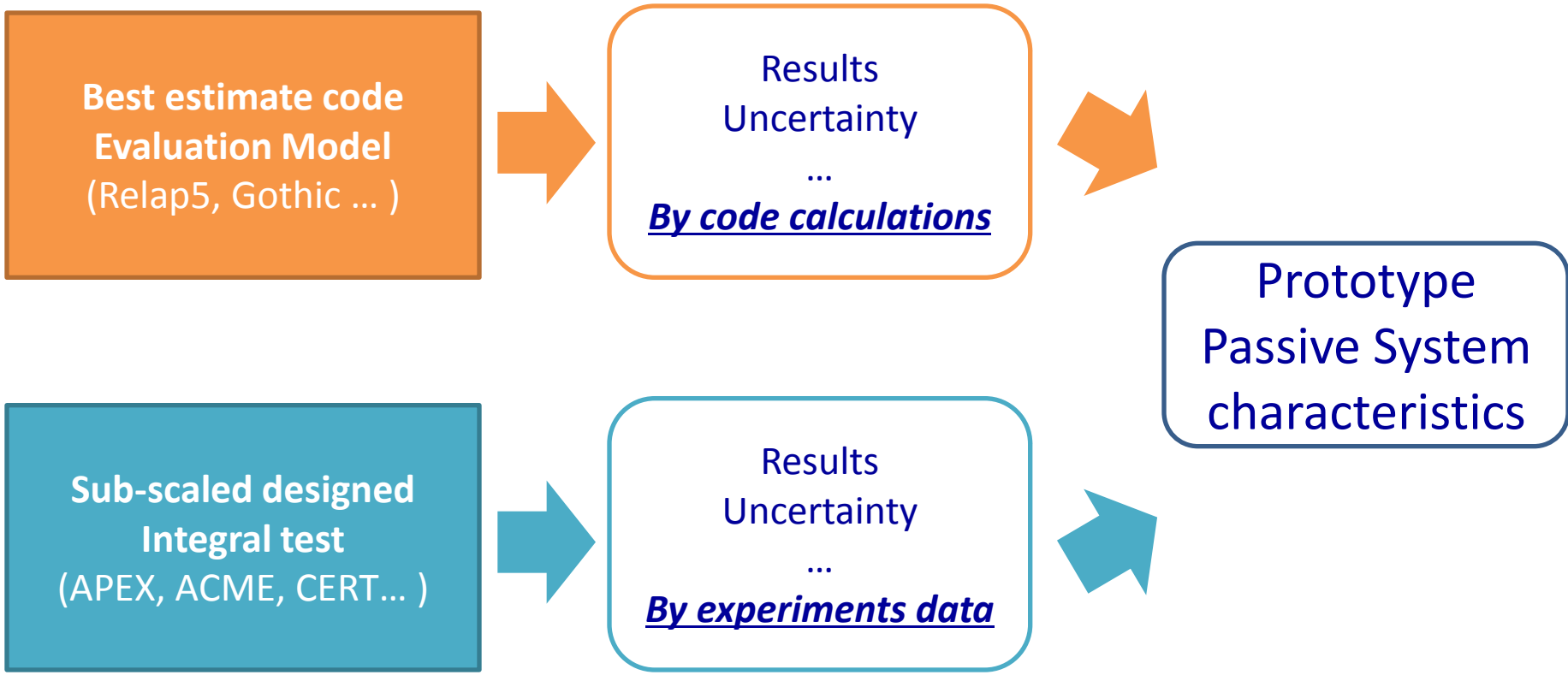


Passive system evaluation process



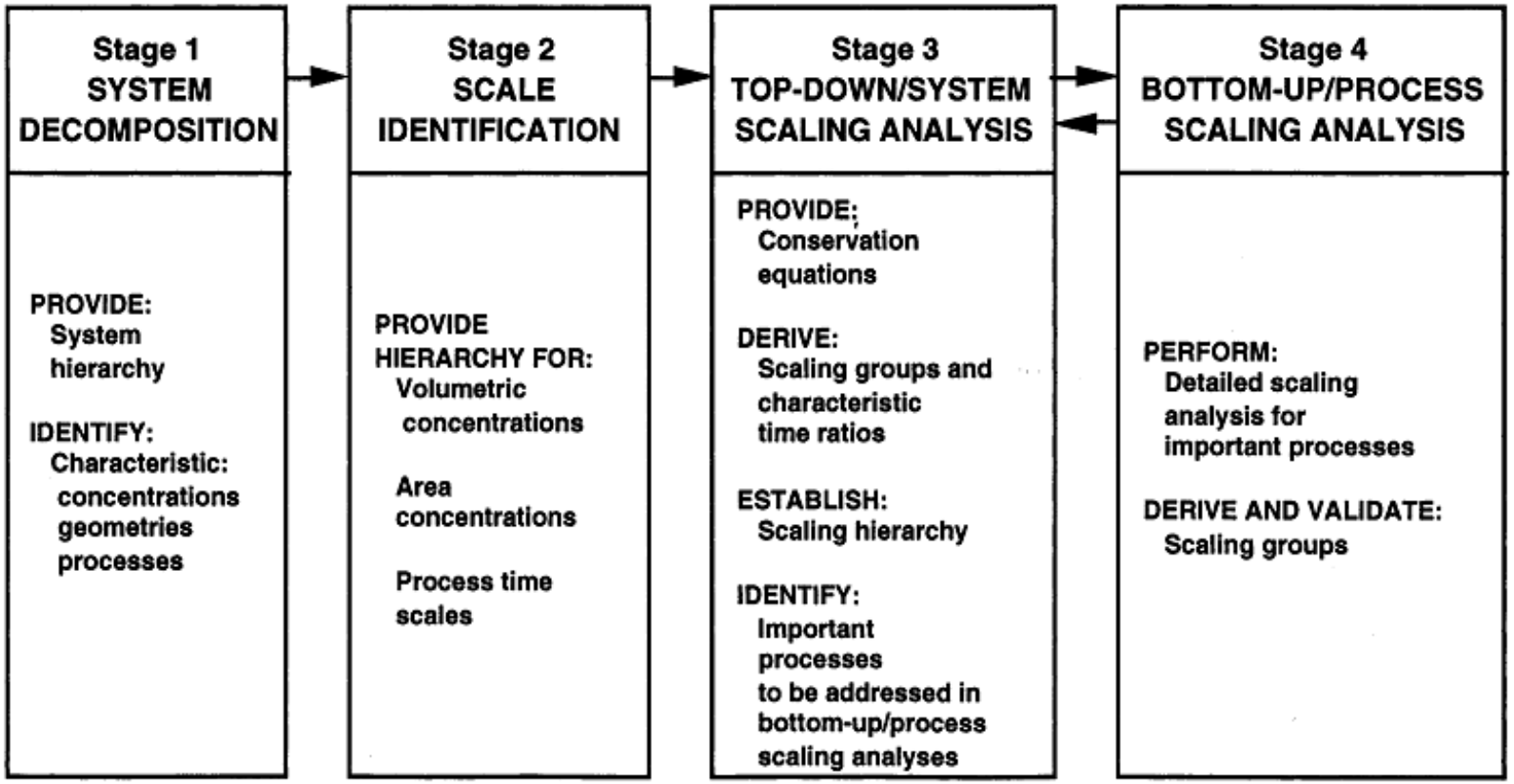
Passive system evaluation process



Evaluation by integral T-H tests

Scaled methodology : H2TS (hierarchical, two-tiered scaling)

PIRT → System→ Critical Physical Phen./Proc → Component → Field → Dimensionless Groups



H2TS flow diagram *fr. Novak Zuber and etc.*

Evaluation by integral T-H tests

Dimensionless value `*i*' of specific physical process `*j*': $\pi_{i,j}$

Prototype dimensionless: π_P

Test dimensionless: π_T

For best simulation to the prototype: $\frac{\pi_T}{\pi_P} \rightarrow 1$

Energy conservation equation:

$$\pi_{p,\tau} XV \frac{dP}{dt} = \dot{m}_{brk}(h_{brk} - h_{stm}) - \sum_{i=1}^{N} [\Lambda(\pi_{p,cond,i}\dot{m}_{stm,i}) + (\pi_{p,q,i} h_{q,i} A_i \Delta T_{if,i})]$$

Evaluation by integral T-H tests

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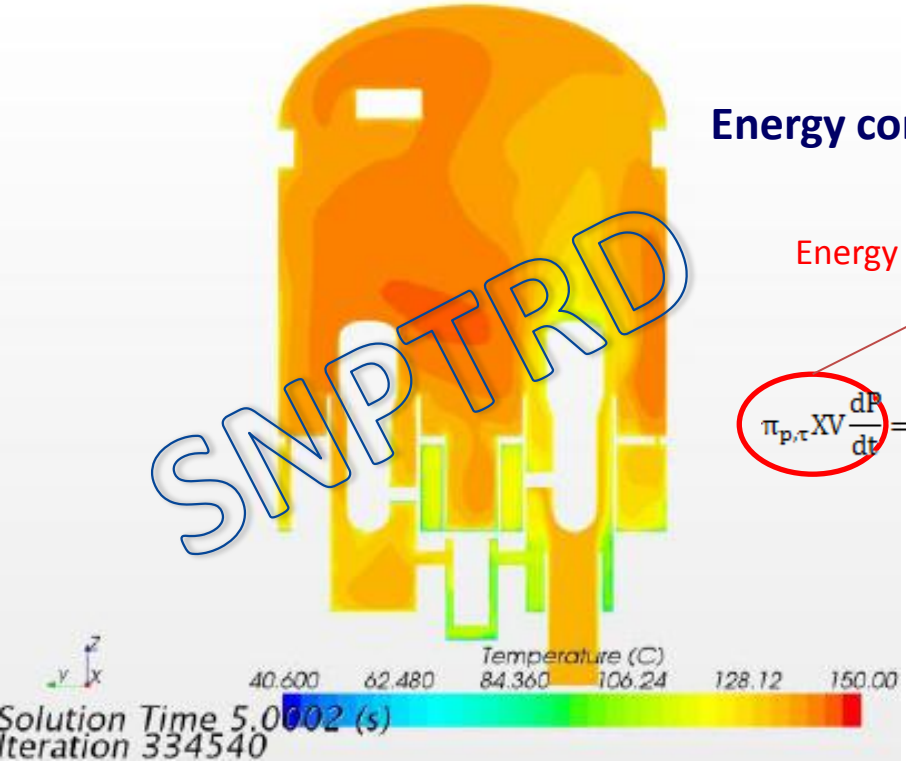

Energy conservation equation:

Energy caused inner pressure change

Absorbed by convection of *i*th comp.

$$\pi_{p,\tau} XV \frac{dP}{dt} = \dot{m}_{brk}(h_{brk} - h_{stm}) - \sum_{i=1}^{N} [\Lambda(\pi_{p,cond,i}\dot{m}_{stm,i}) + (\pi_{p,q,i} h_{q,i} A_i \Delta T_{if,i})]$$

Released by steam brk.

Absorbed by condensation on *i*th comp.

Evaluation by integral T-H tests

Dimensionless value `*i*' of specific physical process `*j*': $\pi_{i,j}$

Prototype dimensionless: $(\pi)_P$

Test dimensionless: $(\pi)_T$

For best simulation to the prototype: $\frac{(\pi)_T}{(\pi)_P} \rightarrow 1$

Pressure expression deduced fr. Energy equation:

$$\left(\frac{dP}{dt}\right)_p = \frac{\left(\pi_{p,\tau} XV \frac{dP}{dt}\right)_T}{(\pi_{p,\tau} XV)_p} - \frac{\left((\Lambda \sum_{i=1}^{N} (\pi_{p,cond,i} \dot{m}_{stm,i}))_p - (\Lambda \sum_{i=1}^{N} (\pi_{p,cond,i} \dot{m}_{stm,i}))_T\right)}{(\pi_{p,\tau} XV)_p}$$
$$- \frac{\left((\sum_{i=1}^{N} (\pi_{p,q,i} h_{q,i} A_i \ \Delta T_{if,i}))_p - (\sum_{i=1}^{N} (\pi_{p,q,i} h_{q,i} A_i \ \Delta T_{if,i}))_T\right)}{(\pi_{p,\tau} XV)_p}$$

Quantitative relationships between the ***test model*** and ***prototype PCCS*** of NPP.

Uncertainty analysis

$$\Delta p_{max} = \Delta p(t)|_{t=t_{pmax}} = \sqrt{\sum_{i=1}^{N} \left(\frac{\partial p(t, x_i)}{\partial x_i} * \Delta x_i\right)^2}|_{t=t_{pmax}}$$

$$p(t, x_i) = \int_0^t f(x_i) \Rightarrow p_{max} = \max[p(t, x_i)] \Rightarrow P[\text{fail of PCCS}] = \text{Prob}[p_{max} > p_{crit}]$$

`*x_i*' represents the i th parameter of relative measurement variables

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Thank you!