

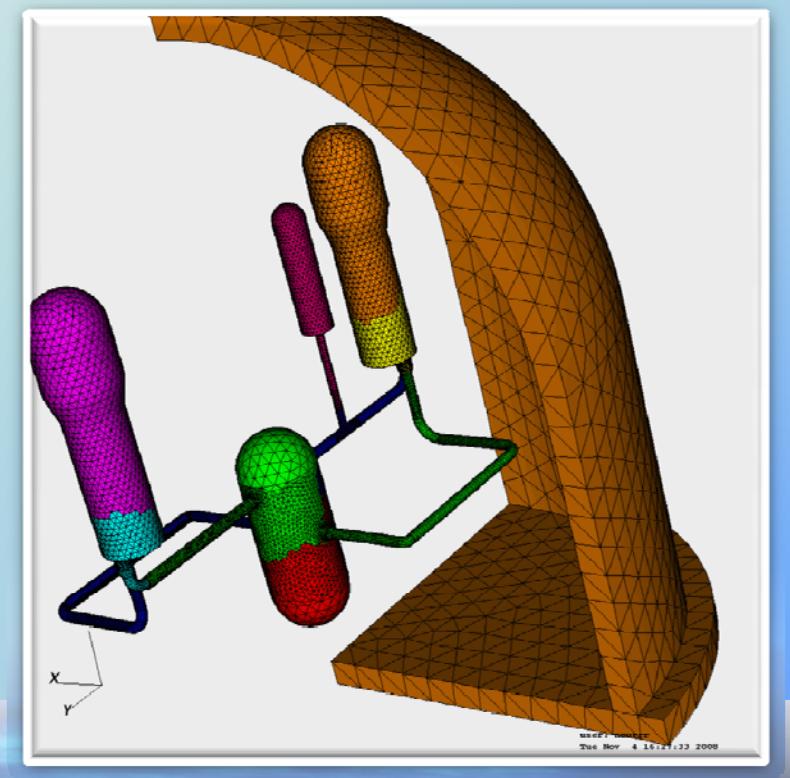


DOE/NRC/NEI Second Annual
Workshop on NPP Long Term Operation
Washington, DC, USA
February 24, 2011

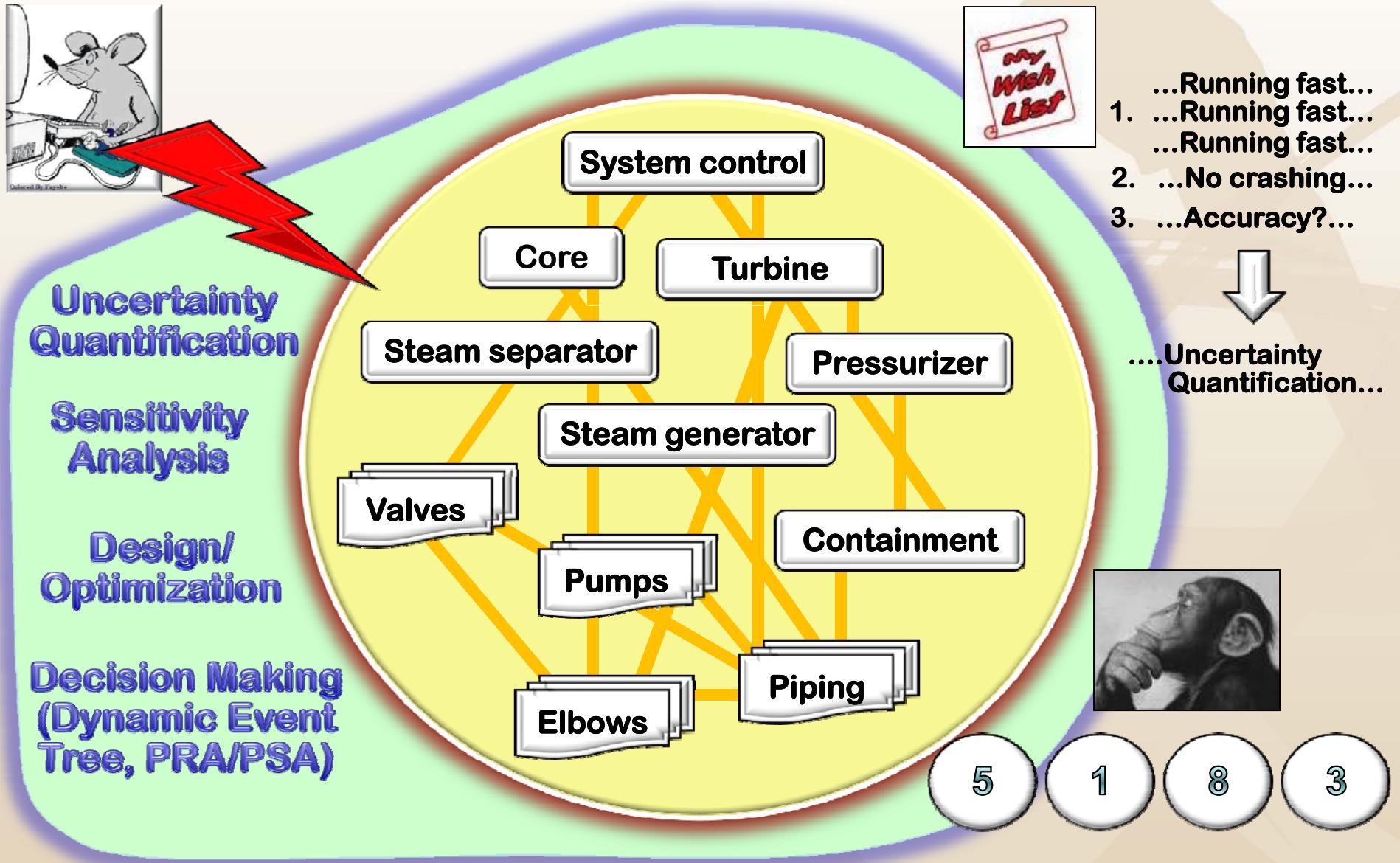
Enabling Methods and Tools for NGSAC in support of life extention

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Idaho National Laboratory (INL)

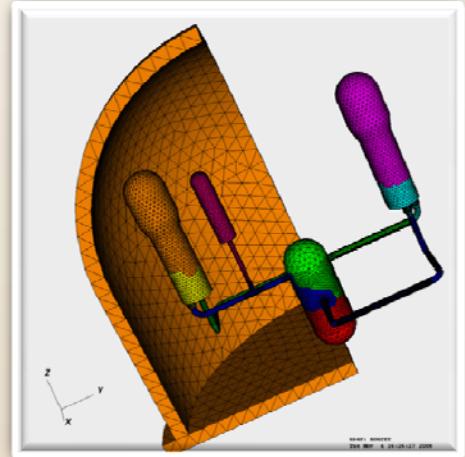


What do you want/expect from NGSAC?



Next Generation Safety Analysis Codes

Safety margin characterization
Balance between design, operation and safety code
Help in decision making
Licensing
Risk monitoring/forecast



Goals:
Reactor Safety and Risk Assessment and Management

LOCA, DBA
(Legacy codes: RELAP5, Trac, TRACE, CATHARE)

Non-DBA
(plant ageing)

System vulnerability search engine

Probabilistic Risk Assessment (PRA)

Simulator: Training



Version β-2 (...transitioning to 1.0...)

- ▶ Object-oriented (C++)
- ▶ Parallel (MPICH)
- ▶ GUI & 3D visualization
- ▶ Cross-platform build (cmake)
- ▶ Database management (SQL)
- ▶ SVN (TRAC/Wiki web-based)



- ▶ All-speed capabilities, t/d consistent real fluid EOSs
- ▶ Boron and corrosion product transport
- ▶ Advanced 2-phase flow modeling
 - Neutronics: 3D nodal diffusion (+FEM)
 - Thermal Structural Mechanics (FEM: stresser/damage accumulation)
 - 3D CFD (LANS, RANS, LES turbulence)
 - Reliability ("Heart beat")
 - Human Factor Modeling

- ▶ High-order space discretization (DG-FEM)
- ▶ Fully-implicit, L-stable, High- order time discretization
- ▶ State-of-the-art linear algebra (Krylov-based, JFNK, PETSc)
- ▶ UQ-enabled (integration with DAKOTA)



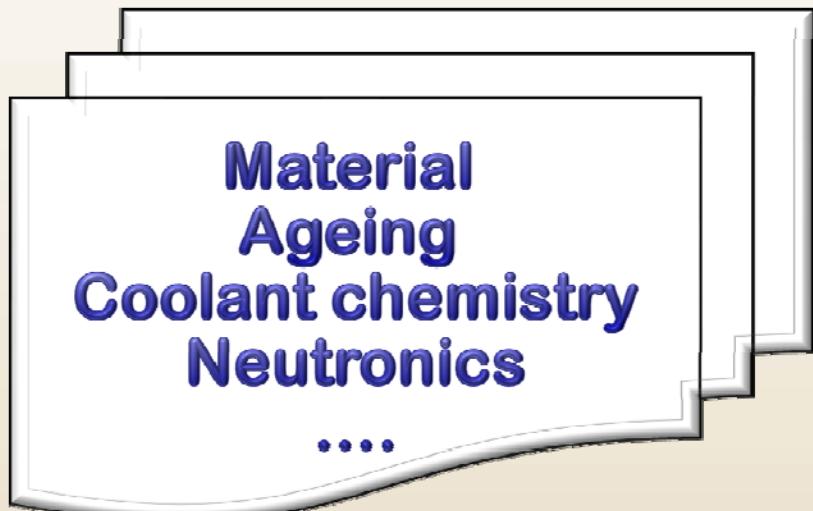
- ▶ Extensive verification
- ▶ Uncertainty Quantification
- ▶ Validation strategy
- ▶ Documentation (html, pdf/latex based manual)
- ▶ Nightly regression testing





R&D Thrust Directions

3D CFD/CG modeling



Advanced
two-phase T/H
modeling

RISMIC, PRA, UQ,
Human Factors

...BETTER NUMERICS...

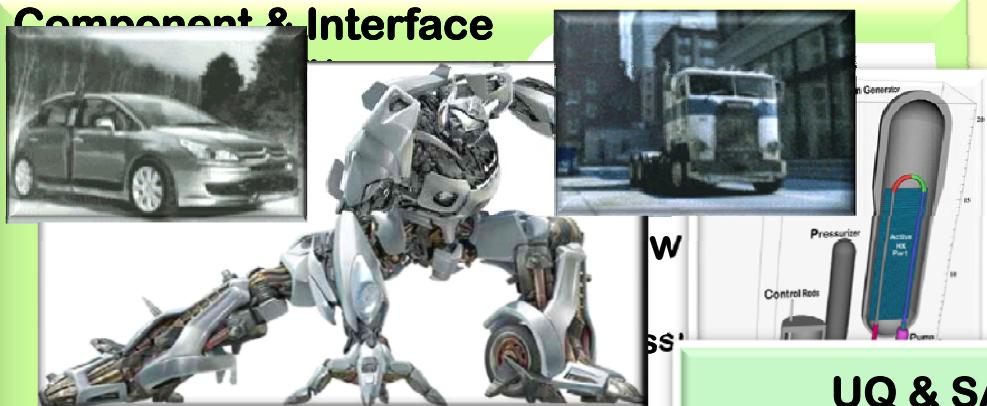


Version β-2: highlights

I/O, GUI, code control utilities

Pre/Post-Processors
(CuBiT, ViSiT, Paraview, ParMeTiS, Zoltan)

Component & Interface



Component Factory

Computational engine
Time discretization,
Transient control

Linear Algebra,
Nonlinear Solvers

PETSc
Trilinos

UQ & SA
Dakota
ADIC (FSA & Adjoint)

Component utilities
and
Library of templates

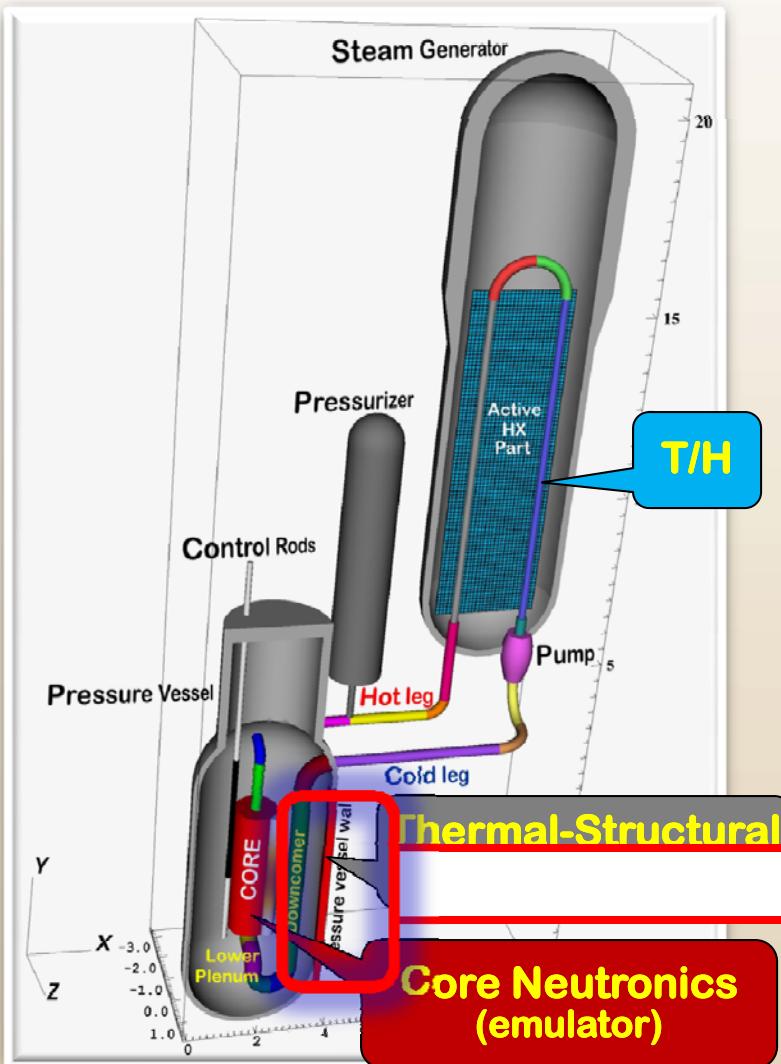
Closure
Library

Material
Library

PWR-I: Ageing



32 components



I. Corrosion products & chemicals transport

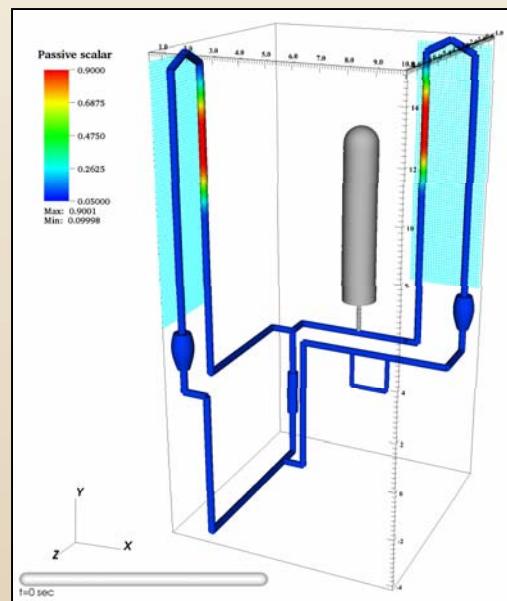
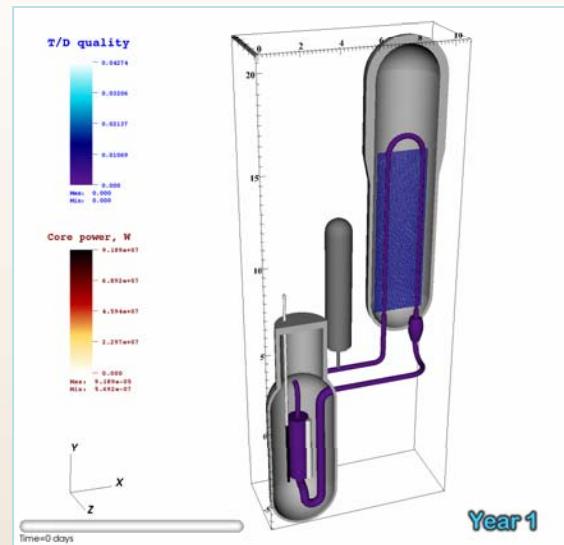
II. High-resolution (CFD-grade)

III. High-resolution neutronics (focus on fluence computation)

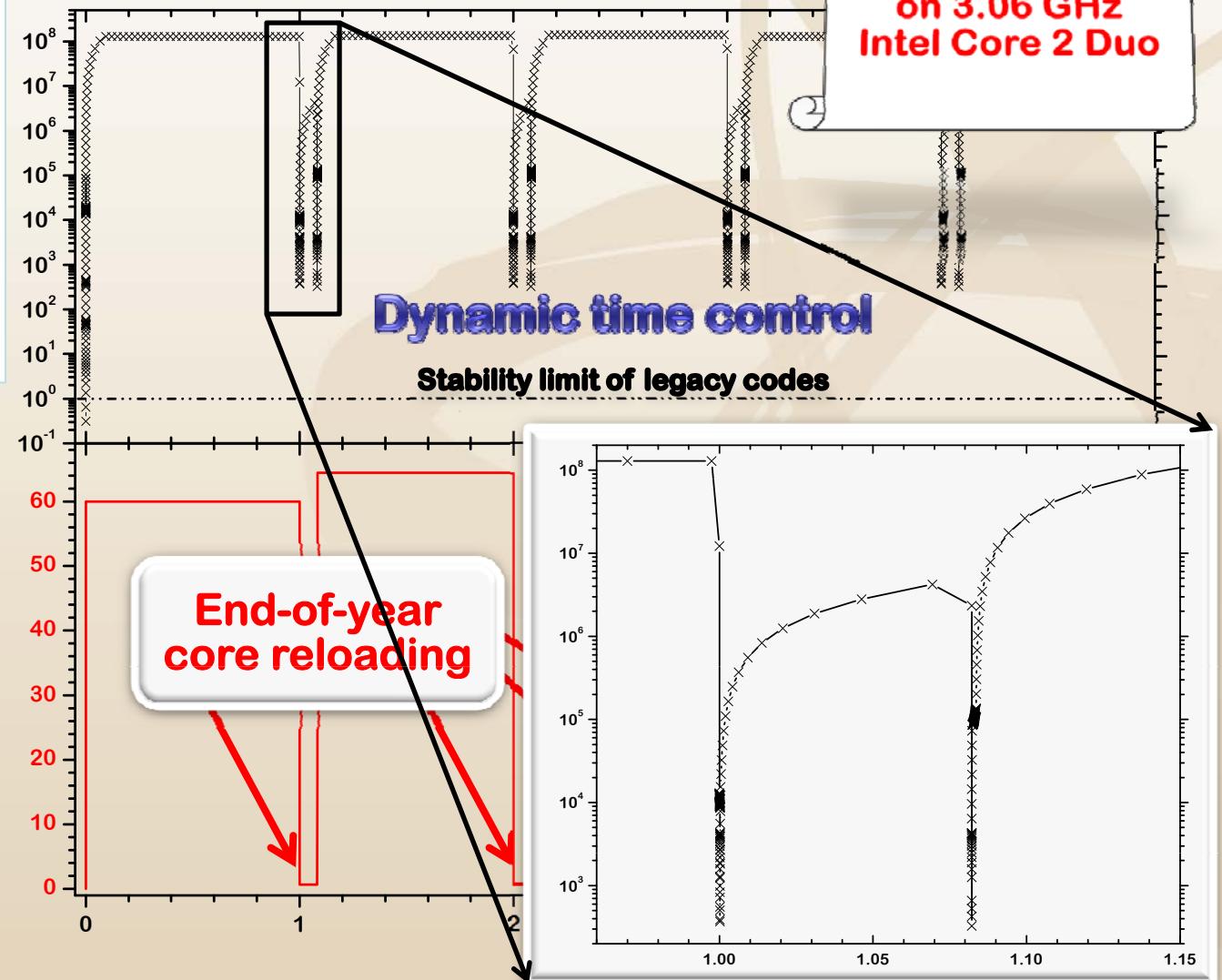
IV. Structural Mechanics + Material degradation/damage accumulation models

Ageing & Damage Accumulation

PWR-I: Ageing



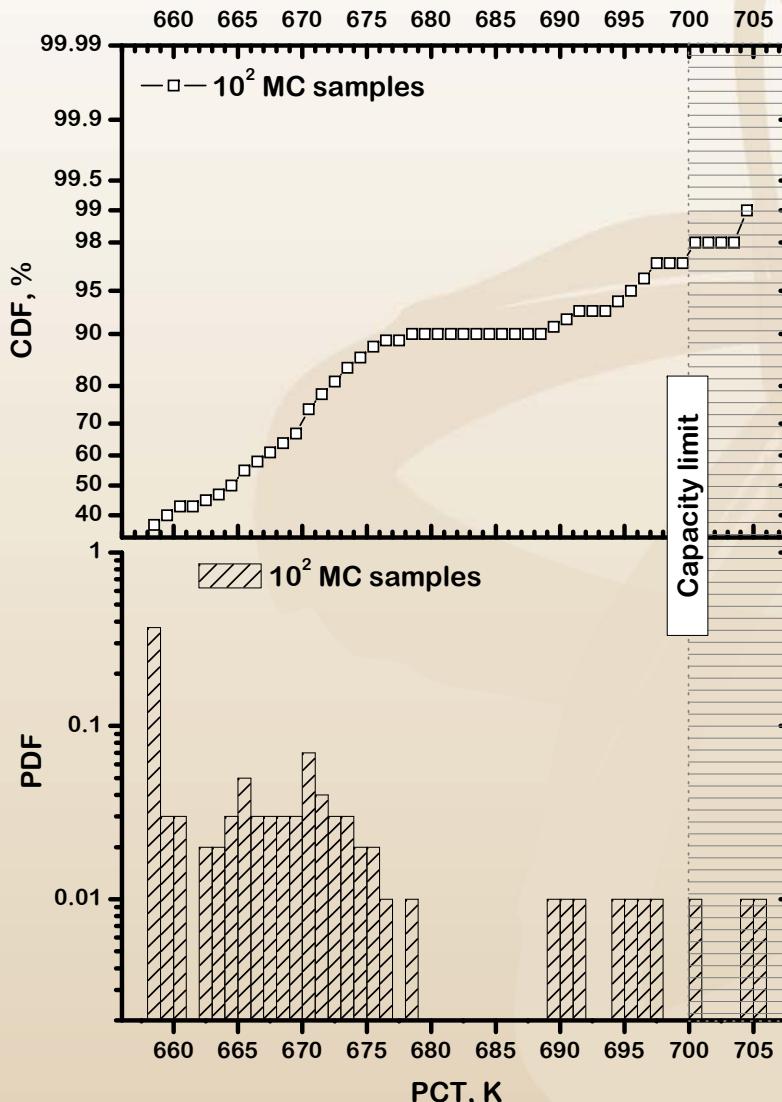
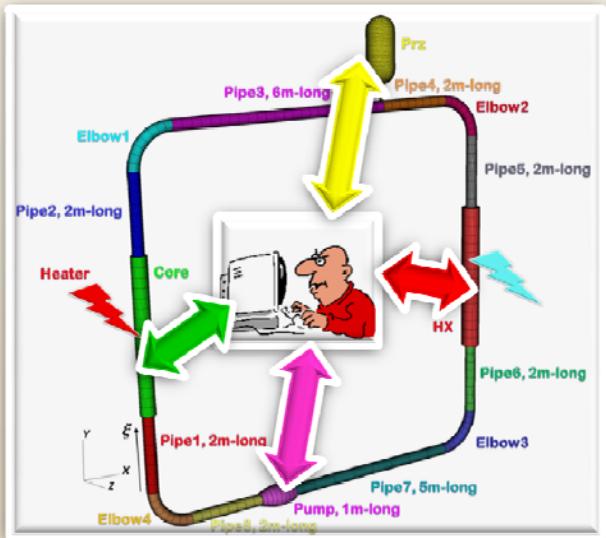
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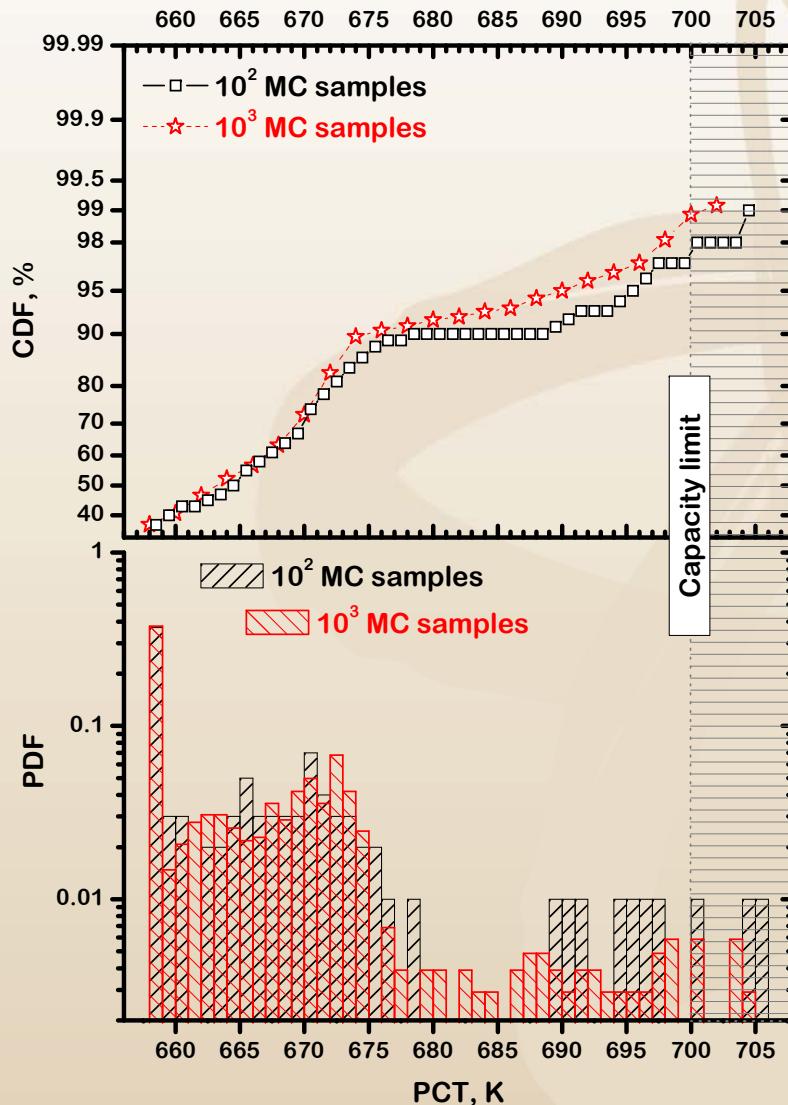
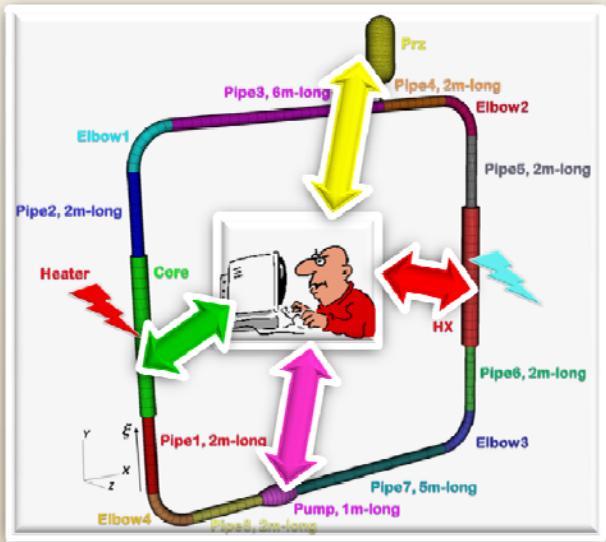
UQ/SA: RISMCA demo

Load Curve for PCT



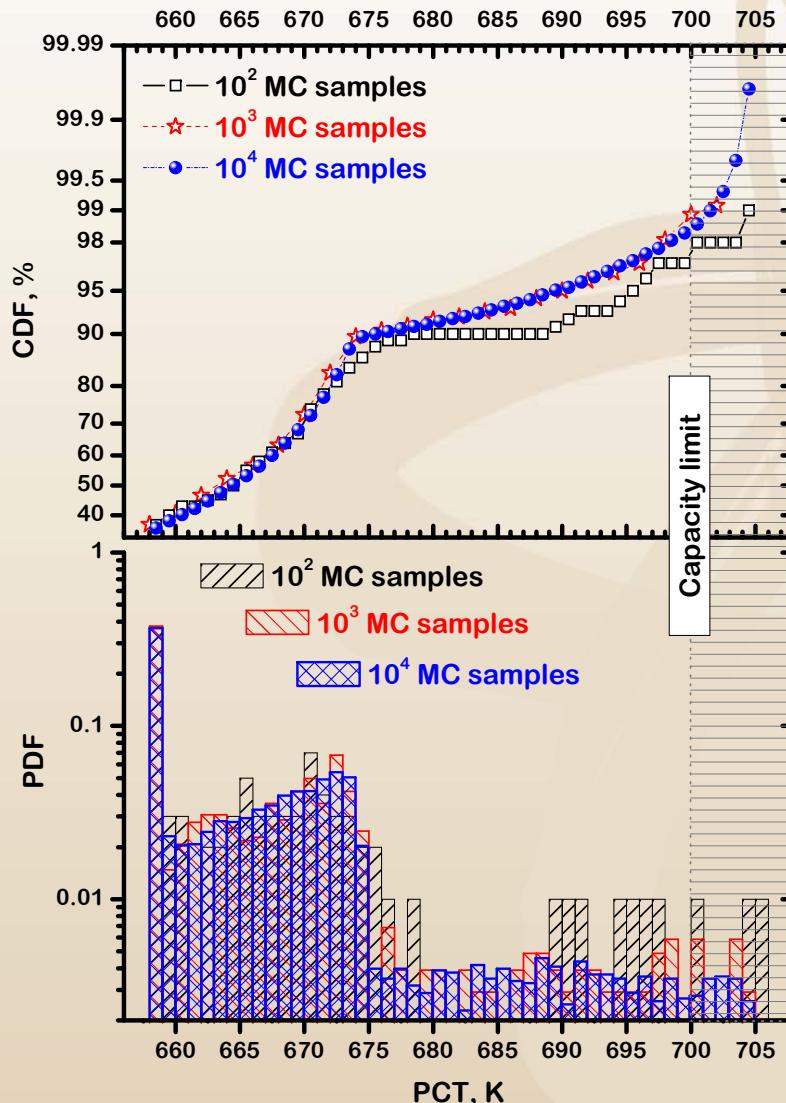
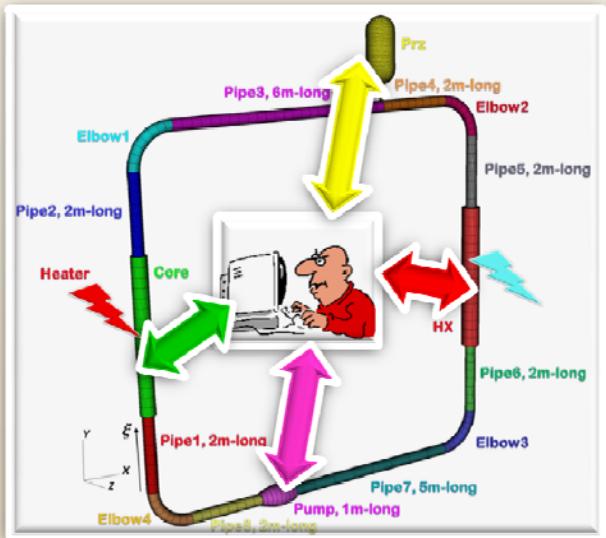
UQ/SA: RISMCA demo

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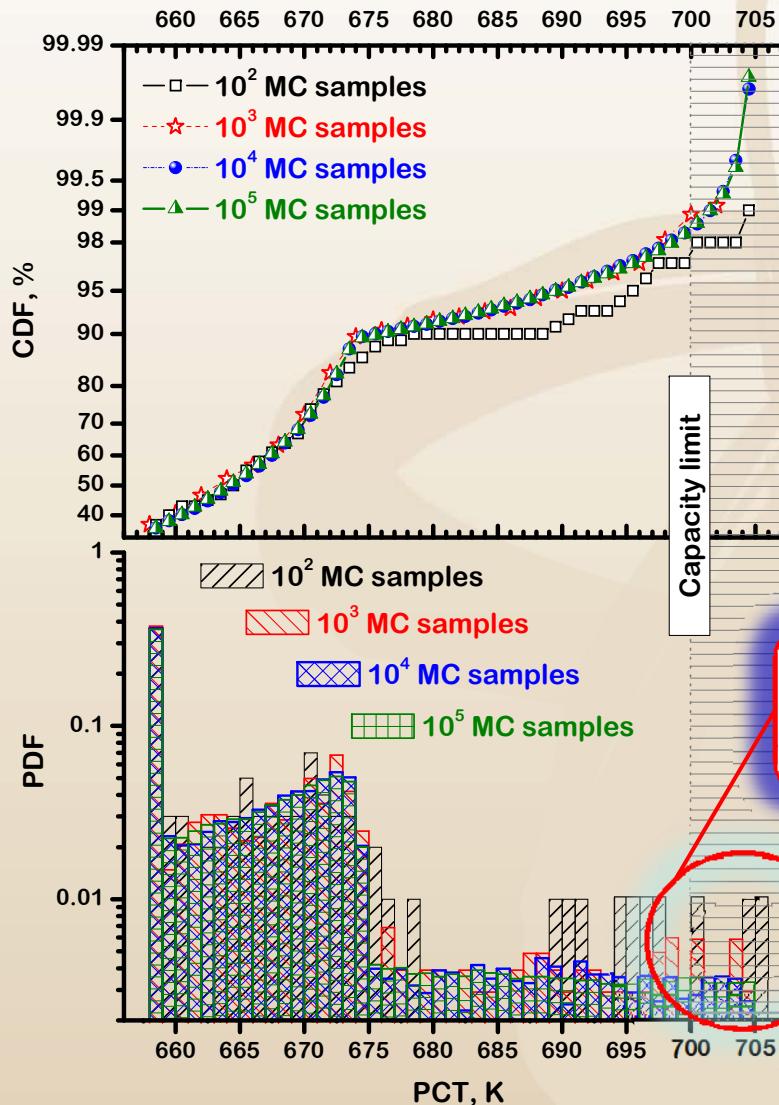




UQ/SA: RISMIC demo

Load Curve for PCT

100,000 runs in ~16hrs
on 512 CPUs of
ICESTORM



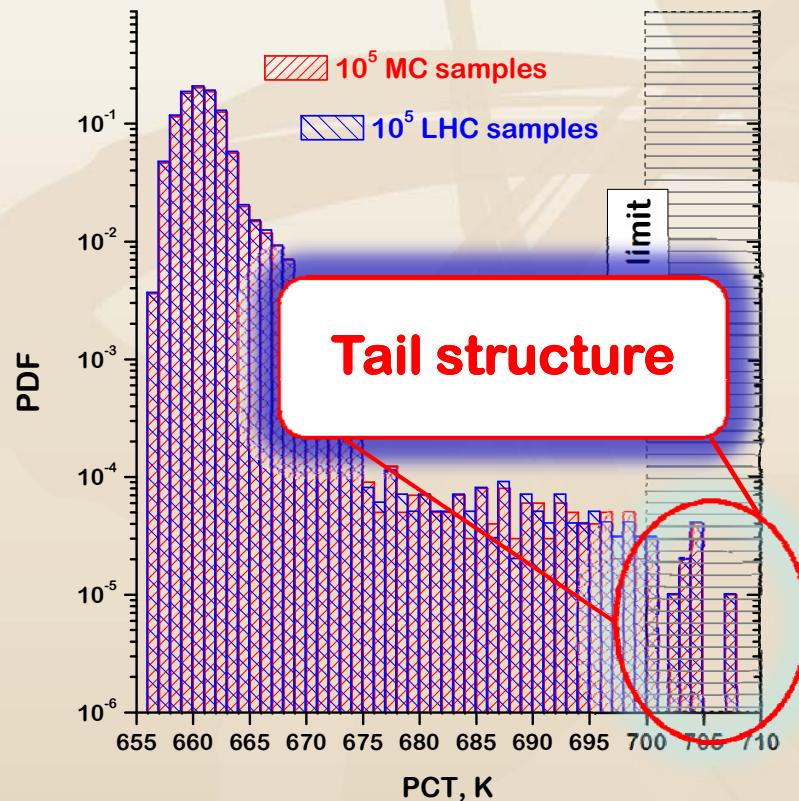
UQ/SA: RISMIC demo



8 scenario parameters
12 modeling/IC/BC parameters
1 discretization parameter



Load Curve for PCT





UQ/SA: RISMIC demo

SNL (DAKOTA):



NEAMS VU

Analytic reliability methods

(transforming the uncertainty quantification problem to an optimization one, where the goal is to find the “most probable point” of failure (MPP))



Laura Swiler, SNL

Stochastic expansion methods

(develop an approximation of a random response function in terms of finite-dimensional series expansions:
polynomial chaos expansion (PCE) and
stochastic collocation (SC))

LANL:

Bayesian-based methods

(Combining LHS sampling with orthogonal ray skeleton, eliminating “inactive” parameters)



Ralph Nelson, LANL

Brian Williams, LANL

NCSU:

Efficient Subspace Method (ESM)

(Reducing parameter space by analyzing and SVD of the covariance matrix) + combining with stochastic expansion methods



Hany S. Abdel-Khalik, NCSU

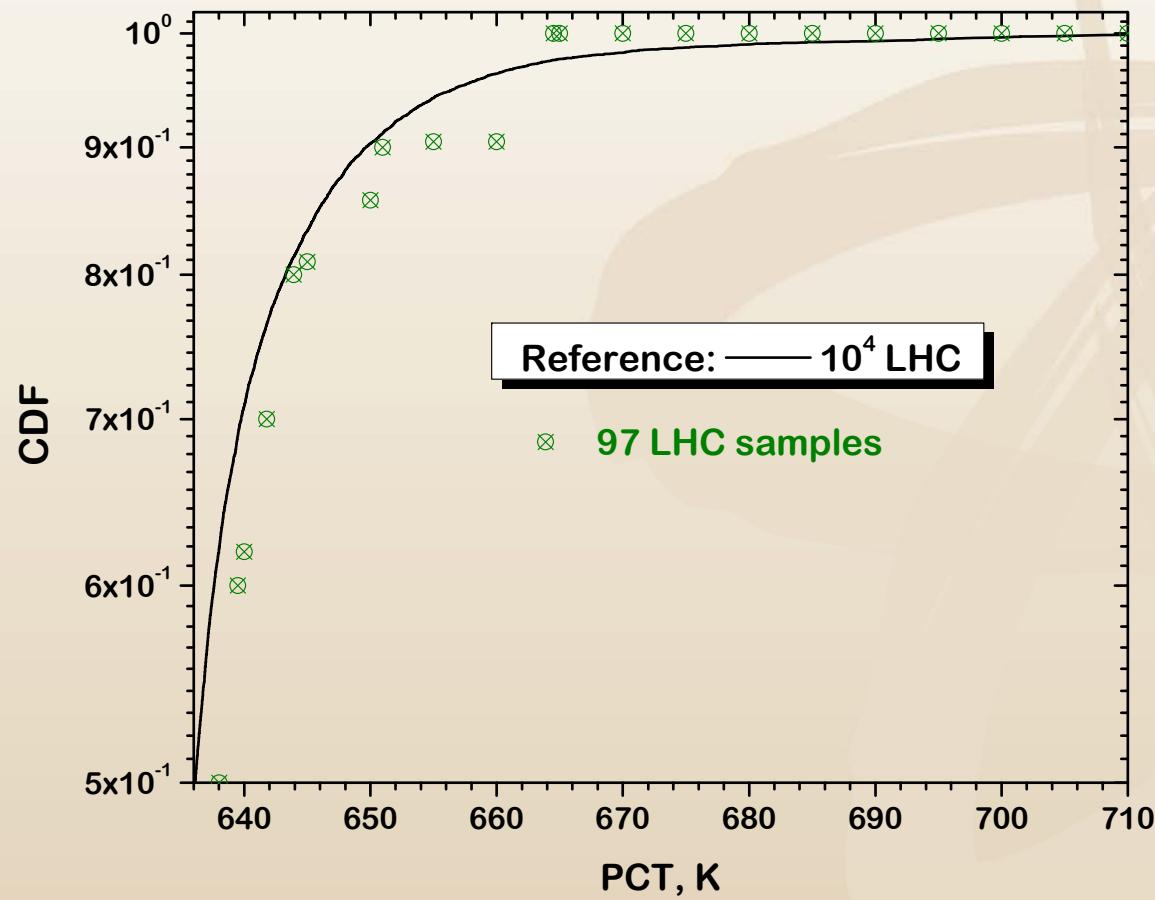


UQ/SA: RISMIC demo

(6 scenario parameters)

Polynomial Chaos Expansion (PCE):

(develop an approximation of a random response function in terms of finite-dimensional series expansions)



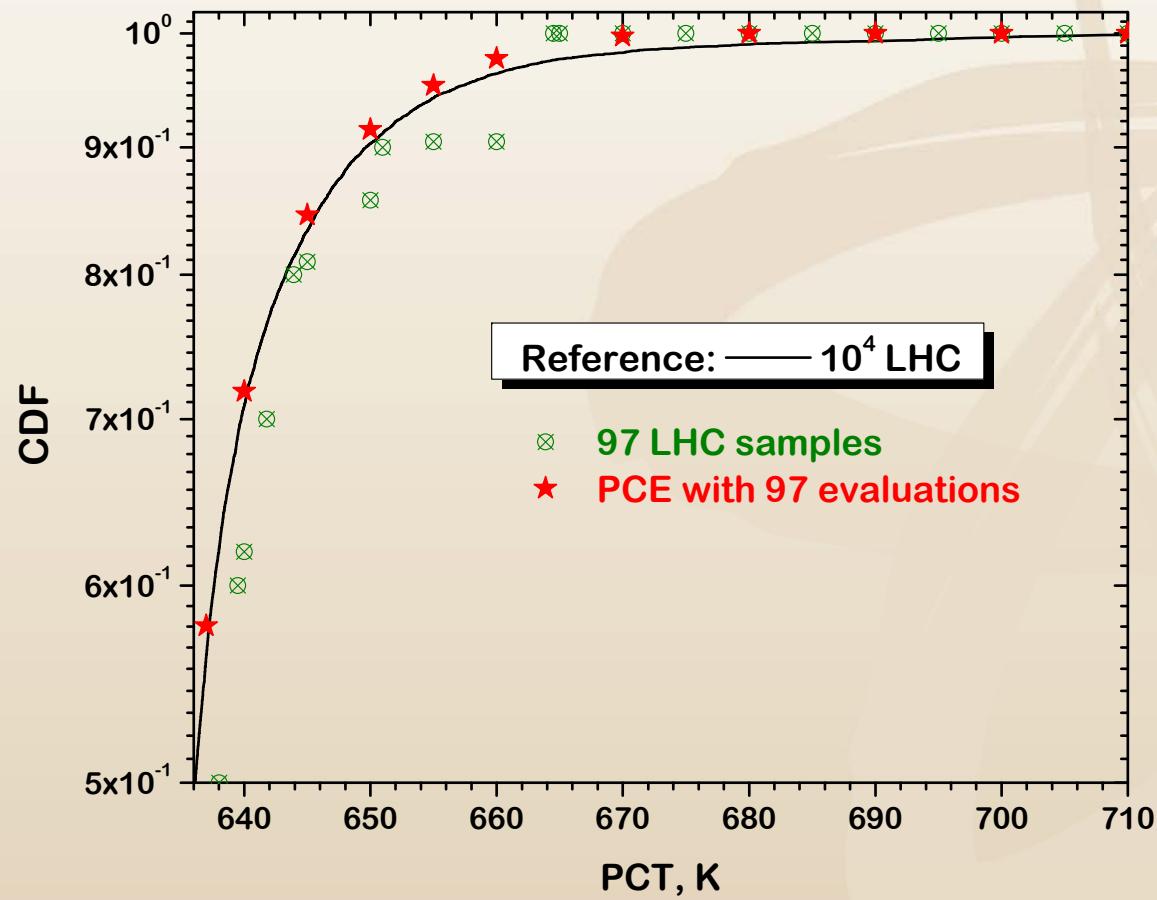


UQ/SA: RISMIC demo

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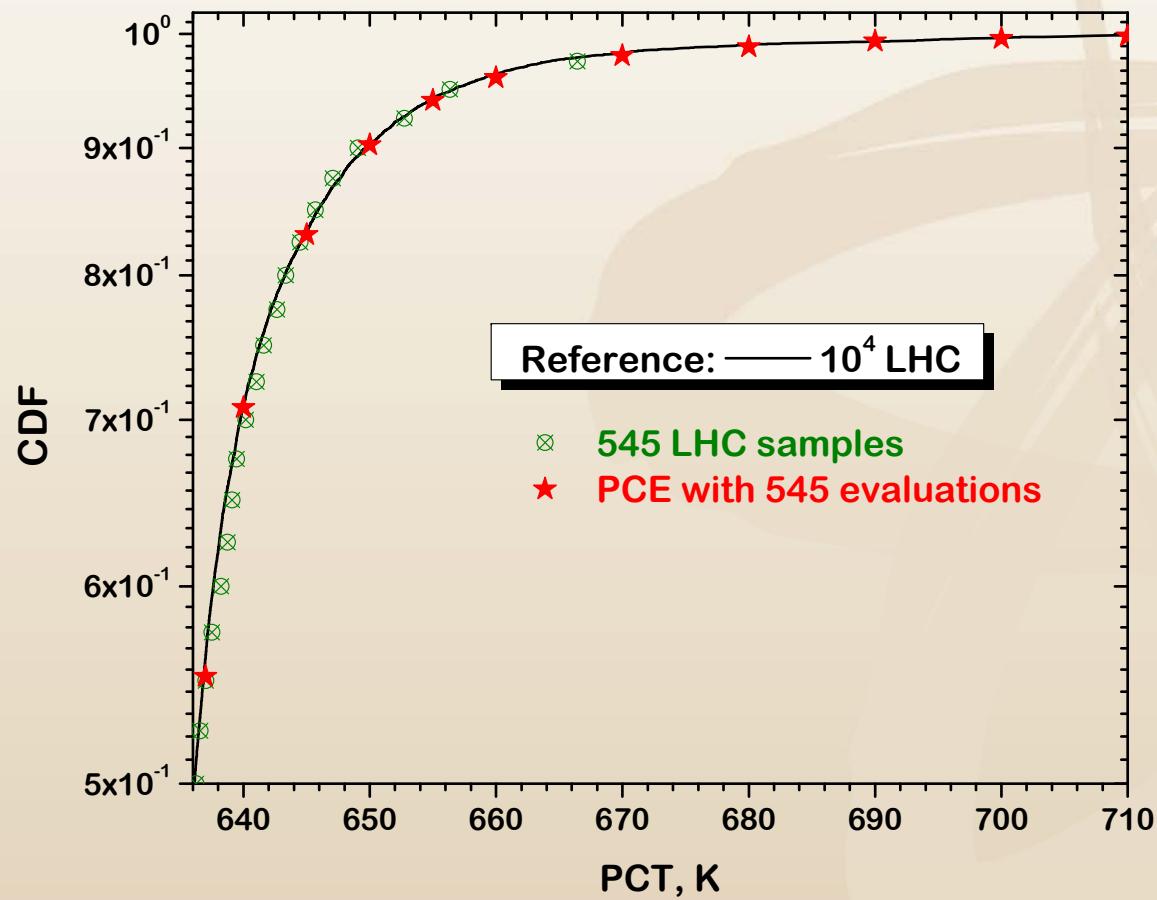
UQ/SA: RISMIC demo



(6 scenario parameters)

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RISMIC demo: Case Studies

LWRS (+CASL)
(EPRI involved)

I. “Feed and Bleed”
(ageing accentuated)

Build R₇ input deck
for a “4-Loop
Westinghouse PWR”
(~2 years)

II. Overcooling
Transients
(mild PTS/ageing accentuated)