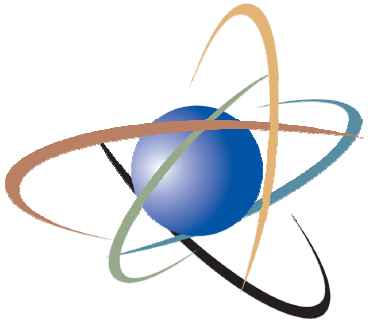

U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

NRC's 3-D Kinetics Code PARCS

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Office of Nuclear Regulatory Research
USNRC

PARCS:
Purdue Advanced Reactor Core Simulator

University of Michigan
Professor Tom Downar

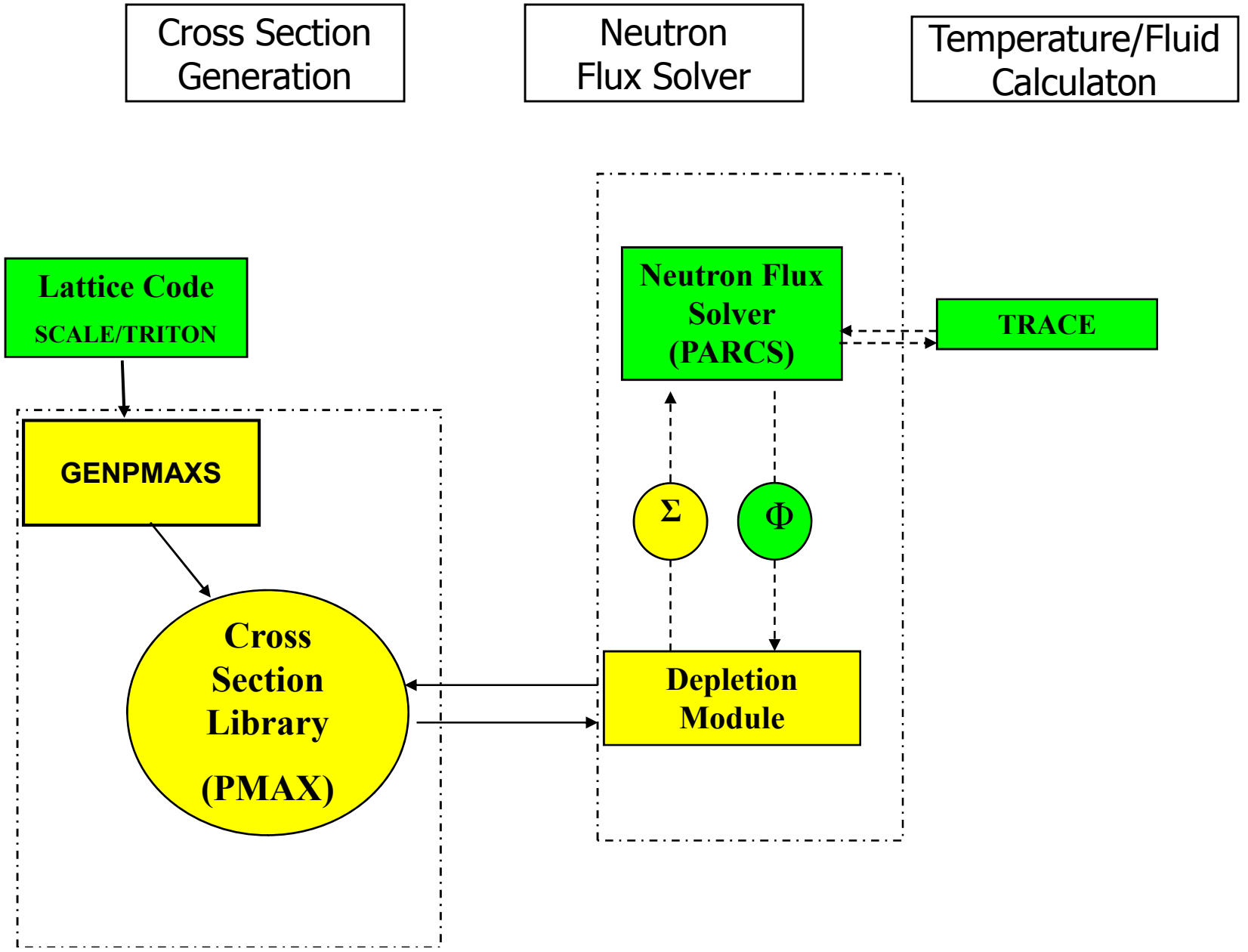
- PARCS solves the time-dependent neutron transport equation to perform 3-D simulations of quasi-steady-state core operations & transient reactor kinetics

$$\frac{1}{v}\frac{\partial \phi}{\partial t} + \Omega \cdot \nabla \phi(r,E,\Omega,t) + \Sigma_t(r,E)\phi(r,E,\Omega,t) = \frac{1}{4\pi} S_f(r,E,t) + \int_{\Omega'}\int_{E'} \Sigma_s(r,E' \rightarrow E, \Omega' \rightarrow \Omega)\phi(r,E',\Omega',t)dE'\,d\Omega'$$

- Uses multivariable tables of nodal cross section data prepared by lattice physics codes (2-D fuel-lattice neutronics and depletion codes)

- Reactor analysis functions performed by TRITON-PARCS resemble those of CASMO-SIMULATE in nuclear industry

U.S. NRC Coupled Code System



PARCS Core Simulator

- **More than 60 International Users / ~10 Papers at PHYSOR on safety analysis w/ RELAP/TRACE/PARCS**

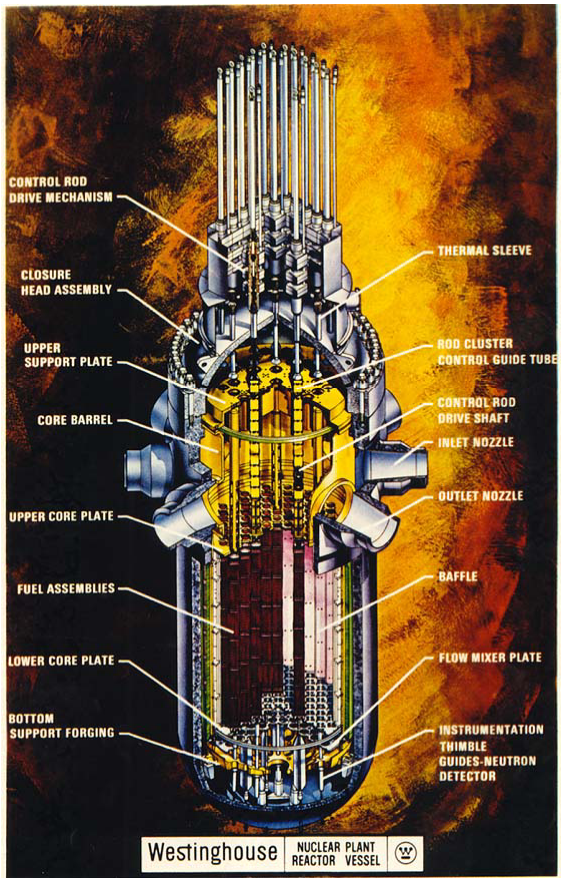
- **Applications:**

  - **Light Water Reactors**

    - **PWR: OECD/NRC Main Steam Line Break, etc**
    - **BWR: Turbine Trip / Stability Analysis**
    - **VVER**
    - **Pressurized Heavy Water Reactor (PHWR)**

  - **High Temperature Gas Reactors**
    - **Pebble Bed Reactors (OECD Benchmark)**
    - **Prismatic Gas Reactors**

  - **PARCS webpage**
    - **http://engineering.purdue.edu/PARCS**

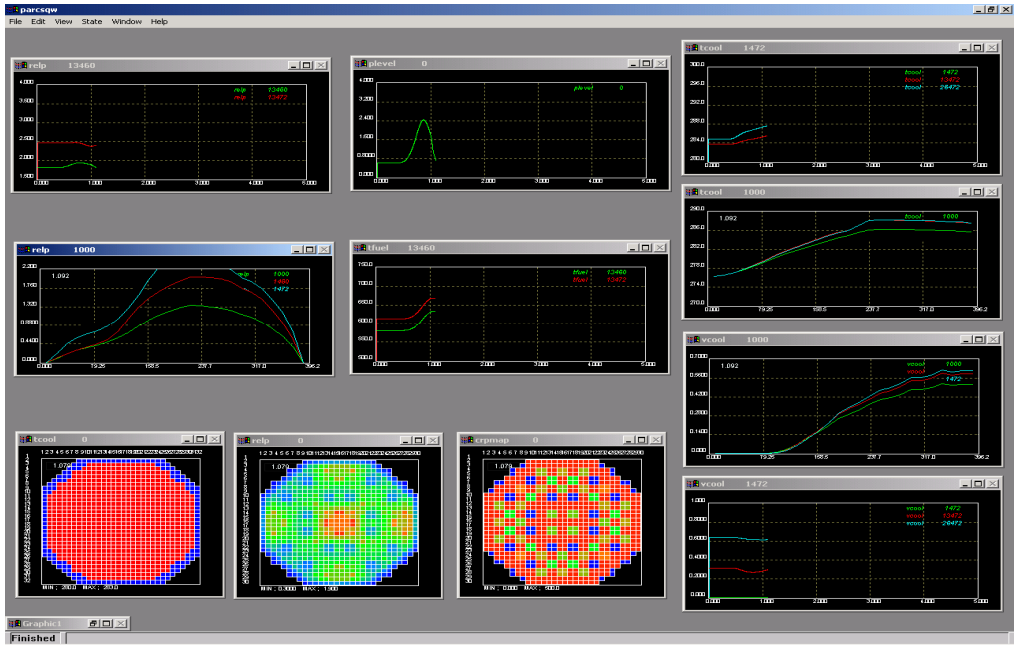


Regulatory Decisions

- PARCS is coupled with TRACE for:
  - analyses of normal operations & transients in operating reactors
  - analyses to support resolution of generic issues
  - evaluation of emergency procedures & accident management strategies
  - confirmation of licensee's analyses
  - testing fidelity of NRC simulators
  - training exercises for NRC staff
  - supporting analyses for certification review of advanced reactor designs

PARCS Main Solution Features

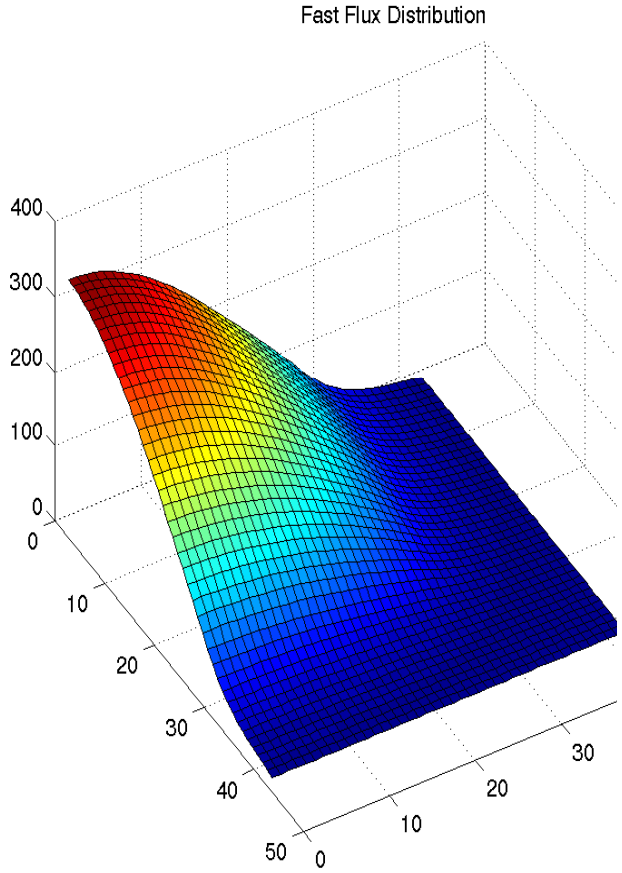
- Steady-state (Eigenvalues) & Transient Simulations
- Multigroup Nodal Diffusion for Rectangular/Hexagonal/Cylindrical Geometries
- CMFD Formulation with Krylov Subspace Linear Solver
- Consistent Pin Power Reconstruction
- Coupled to both RELAP5 and TRACE
- Macroscopic Depletion for Fuel Cycle Analysis
- Multidimensional Cross Section Table Functionalization
- Graphical User Interface:

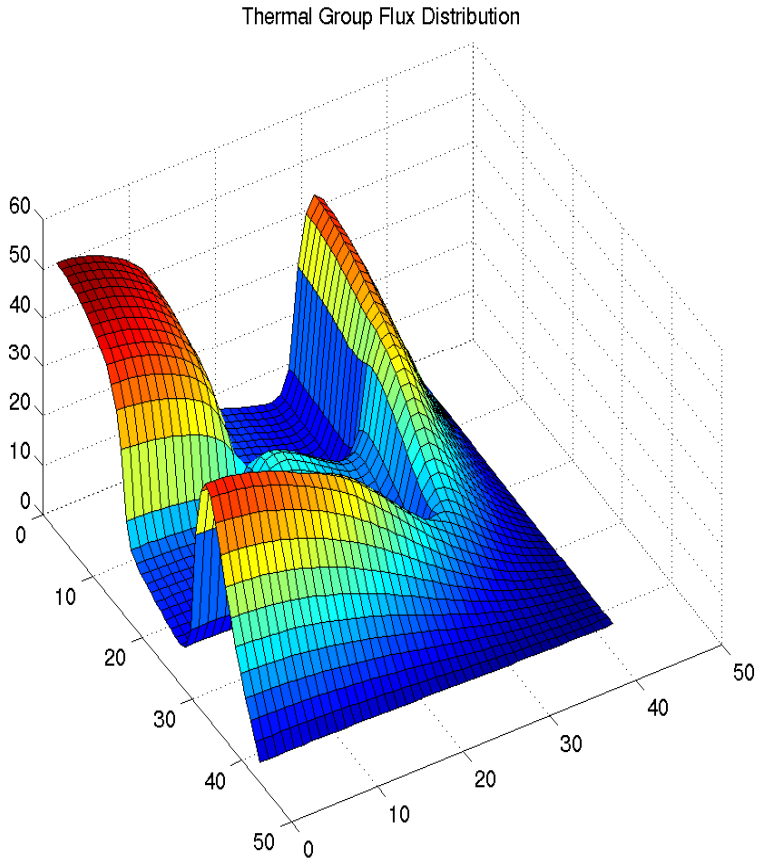


Code Assessment / Application

- Stand-alone Neutronics Tests
  - NEACRP-L336 Pin Benchmark
  - NEACRP PWR Rod Ejection/Withdrawal Benchmarks
  - VVER1000 Rod Ejection Benchmark
  - VENUS-2 Critical Benchmark
  - OECD MOX Core Transient Benchmark
- PWR
  - OECD/NEA Main Steam Line Break (1997)
  - Small Break LOCA (Control Rod Drive Cracking)
- BWR
  - OECD/NEA Peach Bottom Turbine Trip (2003)
  - OECD/NEA Ringhals Stability Benchmark
- Other Reactors
  - VVER OECD/NEA MSLB Benchmark
  - Advanced CANDU Reactor LOCA
  - Pressurized Heavy Water Reactor: ATUCHA
  - VHTR (PBMR/Prismatic)
  - Sodium and Gas Fast Reactors

NEACRP L336 MOX Core Benchmark: Test of Advanced Flux Solvers

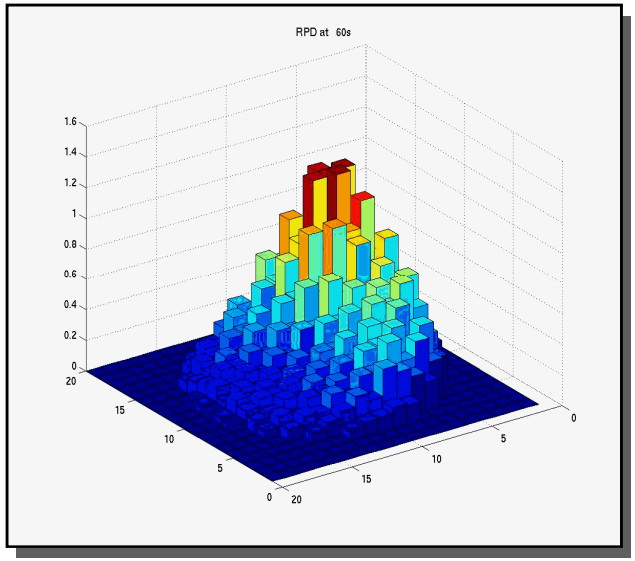




Application to Light Water Reactor Transient Analysis

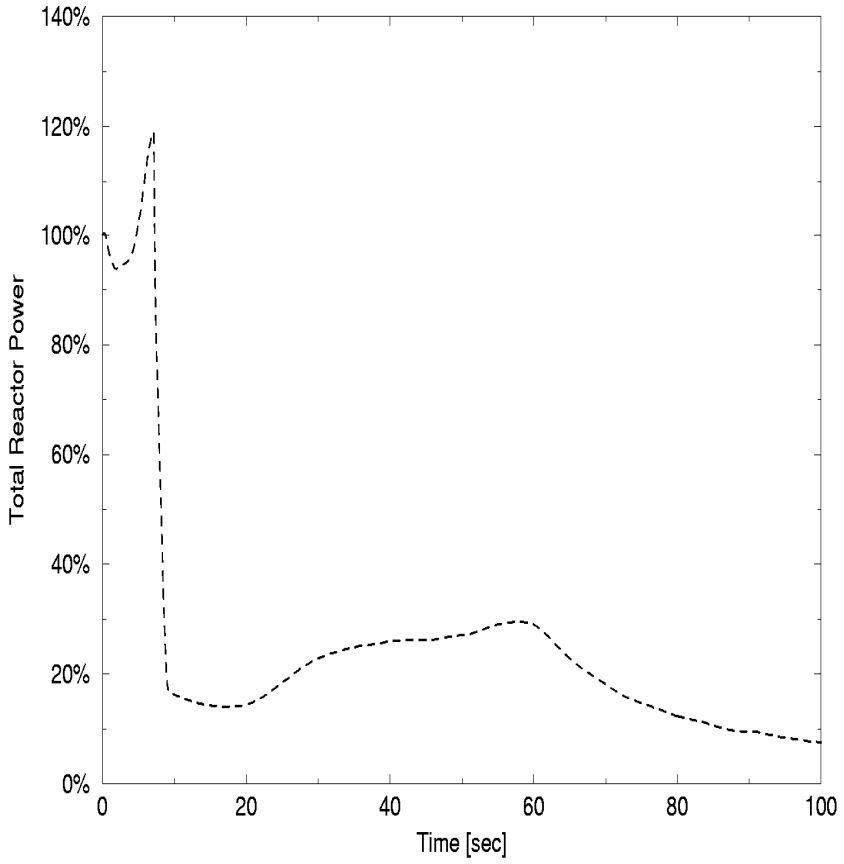
OECD/NEA Main Steam Line Break

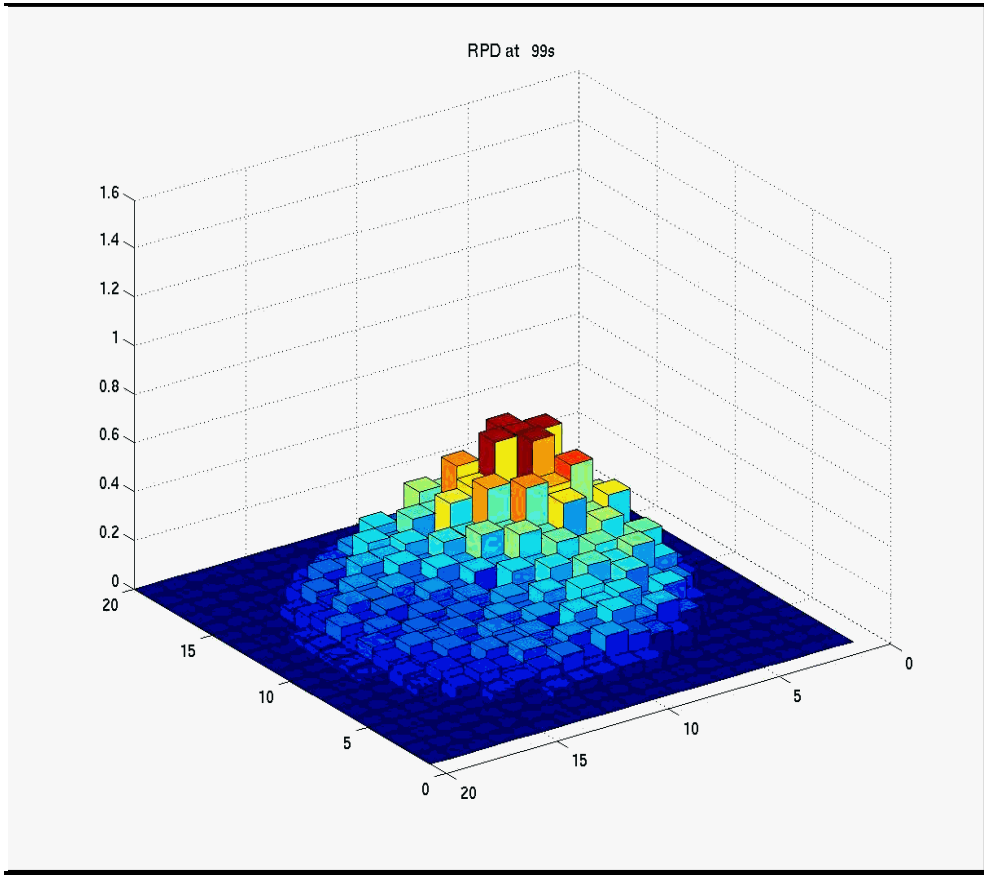
- Break of a Main Steam Line in a Secondary Loop
- Sudden (Secondary Side) Pressure Decrease in Steam Generator
- Enhanced Heat Removal from Primary to Secondary (Easy Evaporation)
- Large Positive Reactivity Insertion
- Distorted Radial Power Distribution Over Time



PWR Application: OECD/NEA MSLB Transient Analysis

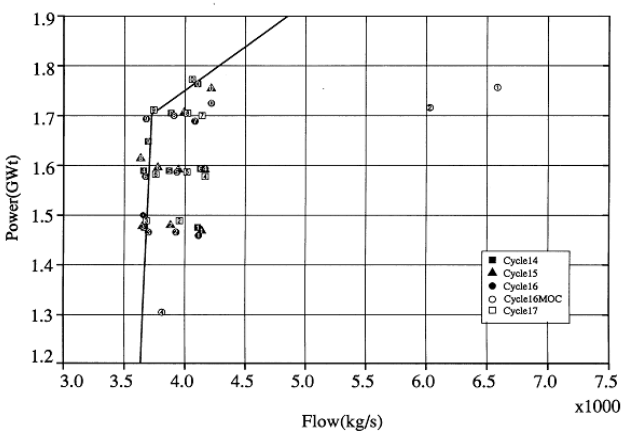
Radial Power Evolution



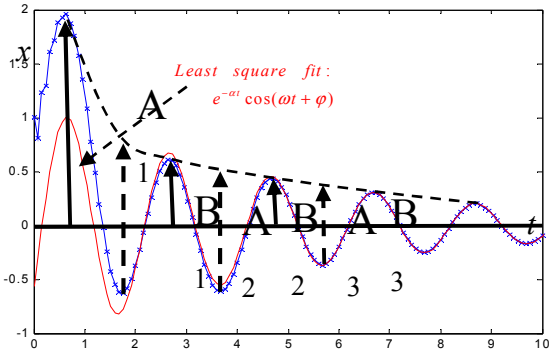


Application of TRACE/PARCS to OECD/NEA Ringhals BWR Stability Benchmark

Test Points



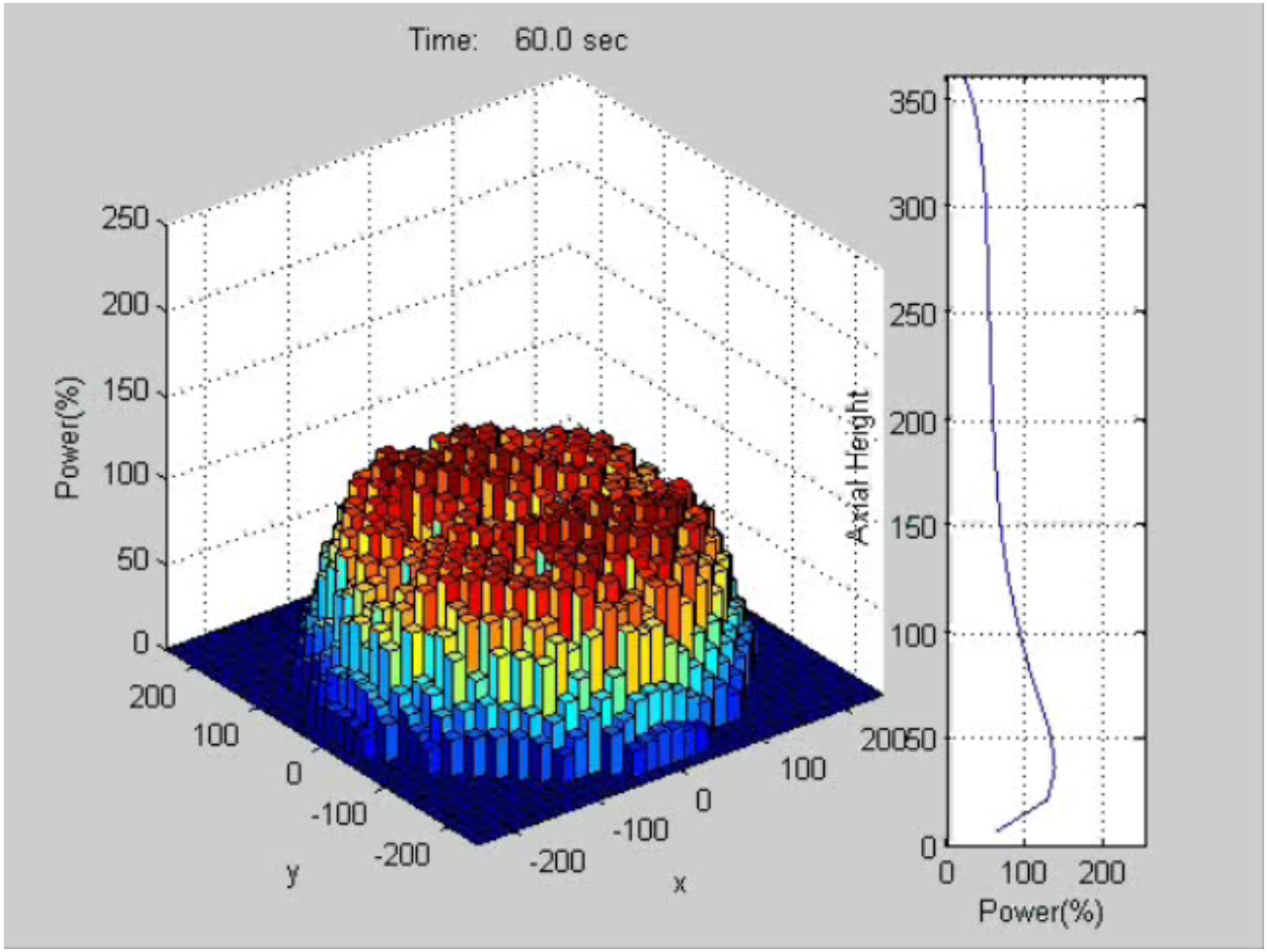
Decay Ratio (DR)



DR: Decay Ratio
TP: Test **P**oint
RAW: Stability analysis with original data
ACF: Auto **C**orrelation **F**unction
IRF:Impulse **R**esponse **F**unction
CR: Control Rod Perturbation
PP: Pressure Perturbation
NS: Noise Analysis

Cycle 14 Comparison of Data and Prediction				
	Reference	Calculated DECAY RATIO		
TP	DR (Global)	CR	PP	NS
3	0.69	0.71	0.69	0.42
4	0.79	0.79	0.77	0.63
5	0.67	0.72	0.71	0.58
6	0.64	0.64	0.63	0.54
8	0.78	0.84	0.83	0.66
9	0.80	0.83	0.82	0.64
10	0.71	0.73	0.73	0.63

Simulation of BWR Stability*



Double Click to start!

*Based on Ringhals model but not a Benchmark Event

Ongoing PARCS Development

- Code modernization (F90), documentation, & configuration control
- Generation of TRACE point kinetics parameters from PARCS steady-state
- Extension of ANM to arbitrary mesh sizes
- Cross section model update for “history” variables
- Multi-cycle & Microscopic depletion capability
- Implicit Code Coupling between TRACE & PARCS
- BWR Stability Analyzer in SNAP
- BWR Pin Power Reconstruction & Detector Model

Future PARCS Development

- Extension to VHTR design (for NGNP)
  - improvements to solution kernel for voided regions
  - spatial heterogeneity effects
  - coupling with MELCOR
  - benchmarking & assessment

- For both the Pebble Bed and Prismatic HTR Designs