RIC 2010
TRACE & PARCS v3.0 - Coupled Thermal-Hydraulic and 3D Neutronic Applications

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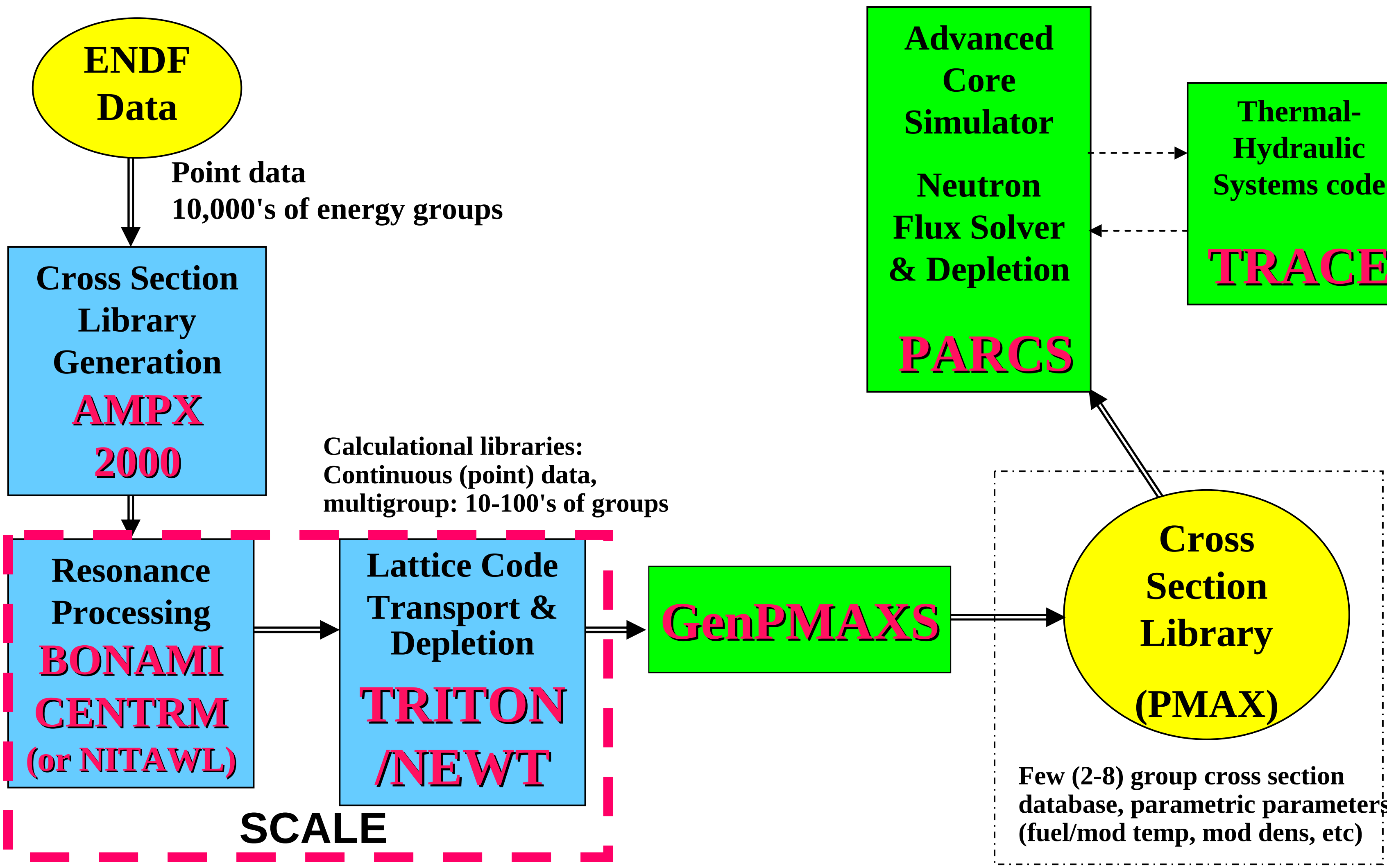
NRC Code Suite



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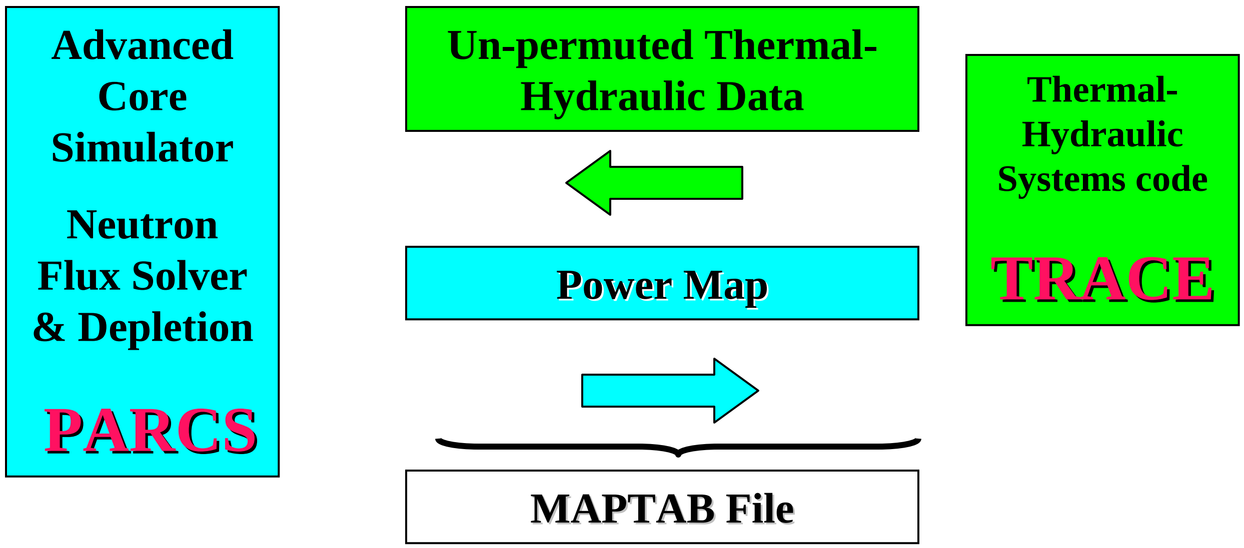
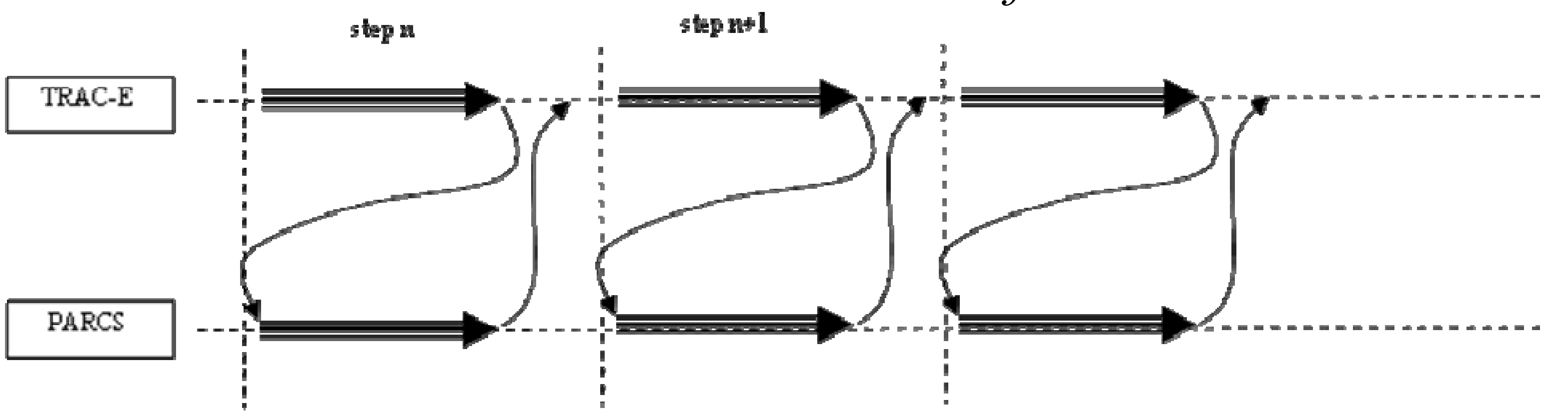
Coupled Calculations



$$N(T)T = Q(\Phi) \quad T: \text{the vector of } T/H \text{ variables}$$

$$M(T)\Phi = S \quad \Phi: \text{the vector of Neutronics variables}$$



TRACE/PARCS

- PARCS-Purdue Advanced Reactor Core Simulator
  - PI: Professor Tom Downar and team at the University of Michigan
- TRACE with PARCS v3.0 offers greater robustness compared to previous versions along with streamlined & modern coding.
- New capabilities include the development of multi-cycle depletion (automated fuel bundle shuffling) and a BWR stability restart deck generator
- The new capabilities are necessary for the NRC to perform BWR Stability & transient audit calculations on new reactor designs and to check increasingly complex applicant and vendor calculations.

PARCS v3.0: Milestones

- PARCS Source Code F90 Conversion
- TRACE Point Kinetics Parameters from PARCS
- Extension of Analytic Nodal Method to non-uniform nodes
- Cross Section Model
- Multi-Cycle Depletion Capability
- Groundwork for Microscopic Depletion
- Groundwork for Implicit Code Coupling
- TRACE/PARCS Stability Restart Deck Generator
- BWR Pin Power Reconstruction
- BWR Detector Model

PARCS v3.0: F90 Conversion

- PARCS v2.8
  - Mixed F77/F90 programming
  - Most of the coding is in F77
  - Memory management is F90 Pointer Declaration /Dynamic Memory Allocation process.
- PARCS v3.0
  - Complete F90 conversion
  - A basic level of code modularization is achieved (i.e., modules that perform a similar function are grouped together)
  - Coding conforms to NRC TRACE Guidelines and Philosophies for code structuring and variable declarations (i.e., explicit variables declarations, REAL(sdk), INTEGER(sik), etc.)

PARCS v3.0: F90 Conversion

- PARCS v3.0 was tested with several OS's & compilers
  - WINDOWS (IVF & CVF); LINUX (Lahey, Intel, Portland, g95); SUN (SUN Fortran)
- PARCS was incorporated into the TRACE Regression Testing System
  - Make-based system built with collection of perl & python scripts
  - Runs desired test suite with desired versions
  - Analyzes & compares the outputs of different code versions
  - PARCS test-suite can be run & report generated as part of regression testing.
  - Coupled T-H/3-D neutronics calculations were added to the TRACE Regression Testing Suite: PBTT-2; MSLB-2

TRACE Point Kinetics from PARCS

- Users had indicated a desire to generate TRACE point kinetics parameters with the PARCS steady state solution
- Consistency established between the PARCS edits of the point kinetics parameters and TRACE
- TRACE point kinetics model:

$$\frac{dP}{dt} = \frac{R-\beta}{\Lambda}P + \sum^{I} \lambda_i C_i + \frac{S}{\Lambda(1-R)}$$

$$\frac{dC_i}{dt} = -\lambda_i C_i + \frac{\beta_i P}{\Lambda} \quad \text{for} \quad i = 1, 2, \ldots, I \ ,$$

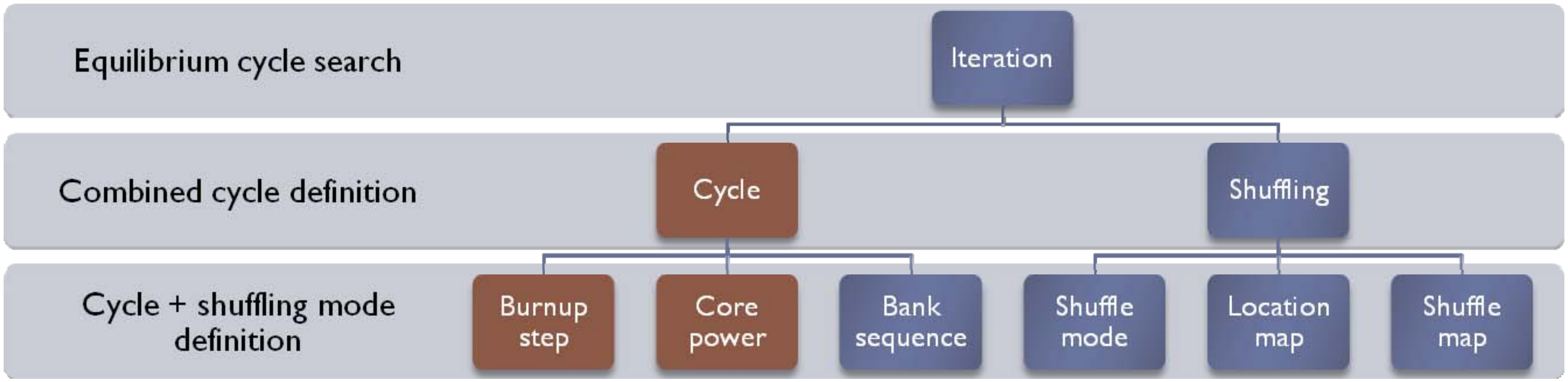
TRACE Point Kinetics from PARCS

Kinetics Option	Description (Transient Card: kinopt field)
0	3-D Spatial Kinetics
1	Point Kinetics with Adjoint weighted cross section change as reactivity excluding the control rod reactivity component
2	Point Kinetics with Adjoint weighted cross section change as reactivity
3	CONVENTIONAL Point Kinetics with Power weighted core average parameter feedback
4	Point Kinetics with Adjoint Fission weighted core average parameter feedback
5	Point Kinetics without feedback (user input reactivity)
6	No Kinetics (user input power levels)

Multi-Cycle Depletion Capability

- Develop methodology for single and multiple cycle depletion
- Previously, to shuffle core, user would manipulate data by hand
- Provide user with interface to employ core shuffling
- Introduce SHUFFLE block into PARCS
- Each single cycle writes a *.core file
- Every assembly is referenced by a user defined ID
- Each shuffle can be followed by another depletion block

Multi-Cycle Depletion Capability



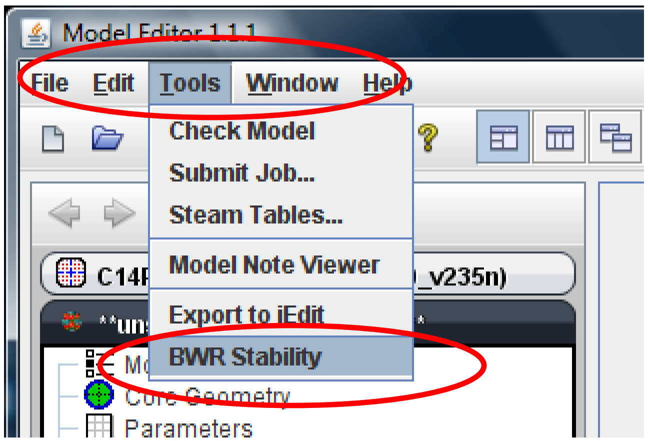

```
CYCLE_DEF    1
TIME_STEP    1*3  3*43  4*33
CORE_POWER   8*95
BANK_SEQ     1 2 3 4 5 6 7 8

CYCLE_DEF    2
TIME_STEP    1*30  3*33  4*30
CORE_POWER   8*100
BANK_SEQ     1 2 3 4 5 6 7 8
```

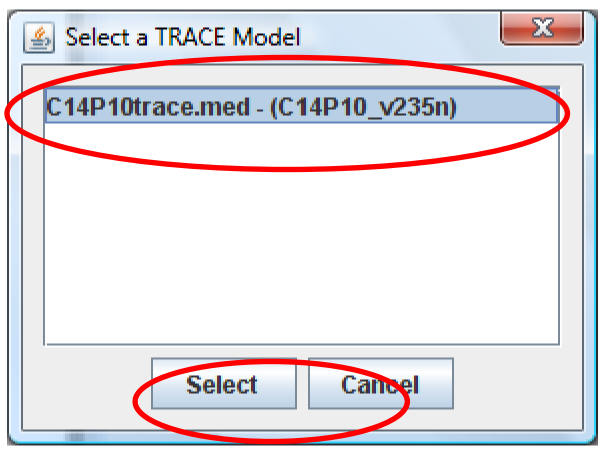
```
!           index              locmap
    BANK_DEF  1     0 0 0 0 0 0 0 0 0 0 0 0 0 0
    BANK_DEF  2     0 167.4 0 0 0 167.4 0 0 0 0 0 0 0 0
    BANK_DEF  3     167.4 167.4 0 0 167.4 0 0 0 167.4 0 0 0 0 167.4
```

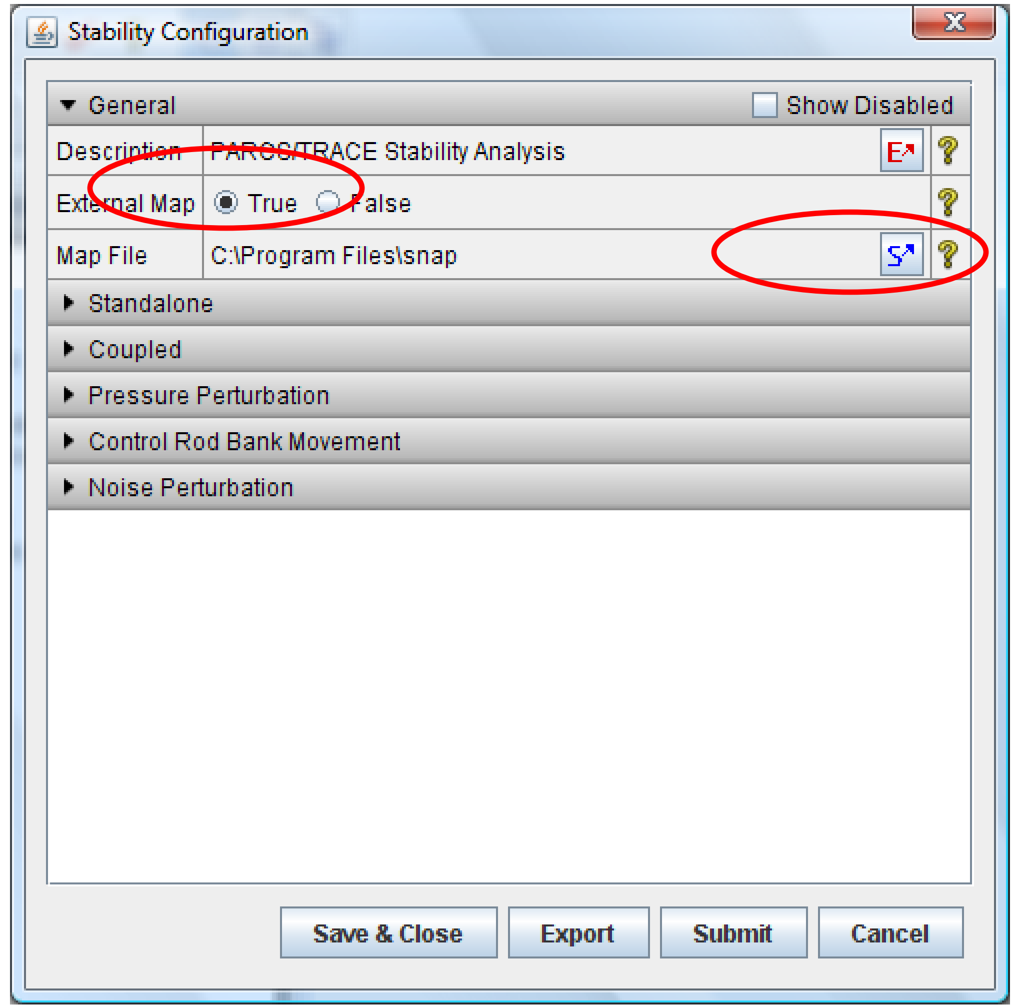
Implicit Code Coupling

- There has been a recent effort to develop a more implicit solution method for the temperature/fluid calculation in TRACE.
- The task here will be to take advantage of this improvement and to make the coupling of TRACE & PARCS more implicit.
  - Algorithm Testing (Matlab)
    - Construct components of matrix
    - For preliminary assessment use simplified single phase 1-D fluid/HT model
    - Construct/perform test problems
  - TRACE Testing/Implementation

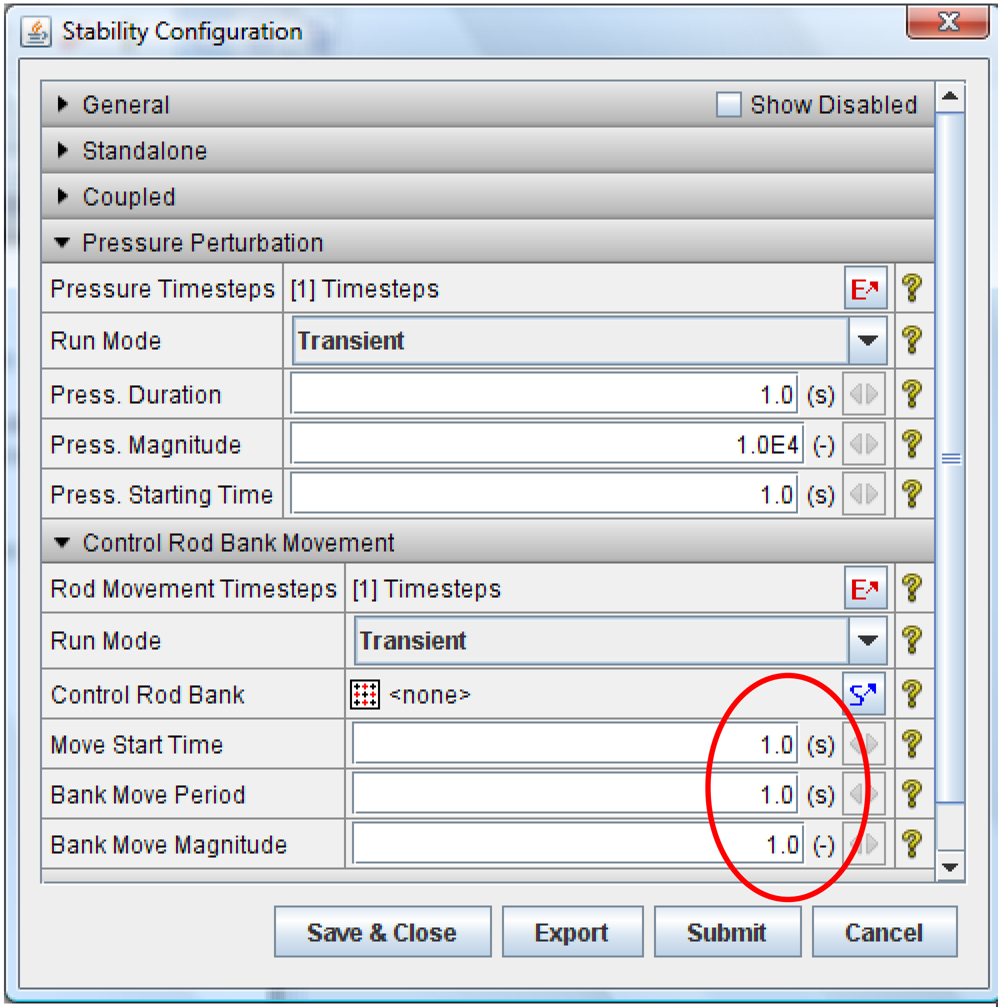
BWR Stability Analyzer



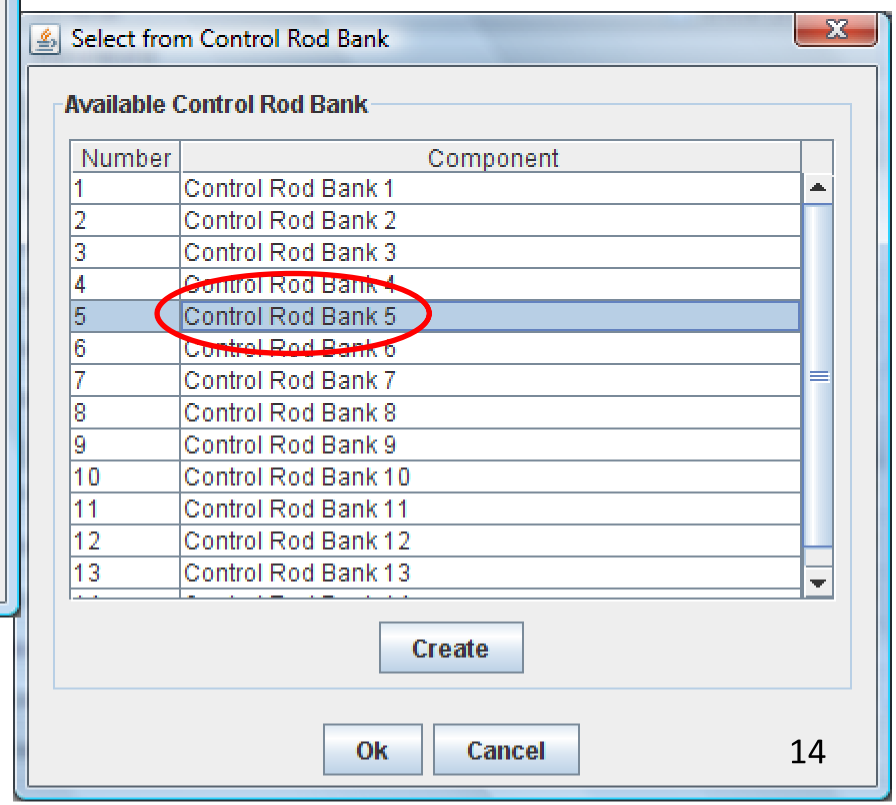




Control Rod Perturbation



- Add time steps
- Select bank



- Specify perturbation

BWR Enhancements

BWR Detector Model

- Detector model added to evaluate responses of LPRM detectors in BWR
- Locations (radial & axial) of detectors should be given to PARCS as user input

BWR Pin Power Reconstruction

- Reconstruct Homogenous Flux with AFEN method
- Critical nodes problem (numerical instabilities associated with flat flux areas)
- Special implementation for BWR pin power reconst.

Conclusions

- Many of the tasks presented are either complete or ongoing (for the longer term tasks)
- Future PARCS LWR work…
  - further restructuring of PARCS source to isolate flux solvers & XS modules within TRACE
  - Additional test problems (SPERT & LOFT)
  - Core mapping checks: 1/8 vs.1/4 vs. ½ solutions
  - Parallelization of XS interpolations
  - Better error checking and warnings (XS's out of range)
  - Possible method to extract power peaking factors from lattice code
  - Refinement of T/H solvers within PARCS models to speed convergence in BWR equilibrium cycle problems