Workshop on DRAGON Practise

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US NRC Workshop on ACR Physics Codes

AECL, Sheridan Park

April 21, 2004

Canada

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EACL Énergie atomique du Canada limitée

Outlines

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  - DRAGON Advanced Features
  - DRAGON Major Modules
  - DRAGON Data Structure
  - DRAGON Documents
- DRAGON Input:
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  - Sample DRAGON Inputs and Outputs
- DRAGON Execution:
  - Side-Step Method
  - Managing a DRAGON Execution with the Side-Step Method
- DRAGON Interface
  - Interface with WIMS-AECL
  - Interface with RFSP-IST

- Part 1: DRAGON Overview

Lattice-Physics Codes

- WIMS-AECL
- WIMS9
- APOLLO2
- CASMO-4
- PHONEIX-P
- HELIOS
- PARAGON
- DRAGON

V&V-ed Industry Standard Toolset in Canada

2D Cell (CANDU, PWR, & VVER) & 3D Supercell capability

Free Software

Why DRAGON?

Consistent with WIMS-IST

Depletion Capability

Collision Probability Method & Method of Characteristics

DRAGON Advanced Features (cont.)

- Industry standard Toolset (IST) Code for CANDU supercell calculation
  - Funding: EPM, HQ, NSERC, AECL, and COG
  - Developed at Ecoly Polytechnique de Montreal
  - version 3-03Bb (IST version)
- General 2D and 3D geometry flexibility
  - LWR, CANDU, VVER, Research reactors, etc.
- Various algorithms for the solution of the neutron-transport equation
  - J± technique
  - IC technique
  - CP technique
  - MOC technique

DRAGON Advanced Features (cont.)

- Self-shielding
- Leakage treatment
- Fuel Depletion
- Perturbation and restart capability
- Modular design
  - Information transferred from one module to the other via the data structures
  - Can be interfaced easily with other production codes
- Coupled with reactor core physics code DONJON

DRAGON Advanced Features (cont.)

- Libraries
  - WIMS-AECL libraries
    - Direct access format only (NDAS format not supported)
    - Winfrith 69-group library
    - ENDF/B-V based 89-group library
    - ENDF/B-VI based 89-group library
  - WIMS-D4 libraries
    - Sequential binary format
    - WIMSKAL 69-group library
    - ANL ENDF/B-VI based 69-group and 192-group libraries
  - MATXS libraries
    - Sequential binary format
    - ENDF/B-V based 69-group library in NJOY-89 MATXS format
    - ENDF/B-V based 70-group library in NJOY-91 MATXS format
  - APOLLO libraries

DRAGON Major Modules

- The library modules
  - MAC: Generate or modify a DRAGON *MACROLIB* which contains the group ordered macroscopic XS for a series of mixture
  - LIB: Generate or modify a DRAGON *MACROLIB* that can read a number of different types of microscopic XS libraries
- The geometry module
  - GEO: Generate or modify a geometry
- The tracking modules
  - EXCELT: CP technique
  - SYBILT: IC technique
  - JPMT: J± technique

DRAGON Major Modules (cont.)

- The self-shielding module
  - SHI: Perform self-shielding calculations
- The assembly modules
  - ASM: Use the tracking information to generate a multigroup response or CP matrix
  - EXCELL: Combine the EXCELT: and ASM: modules, avoiding the generation of an intermediate binary tracking files
- The flux module
  - FLU: Solve the linear system of multigroup response or CP matrix equations for the flux

DRAGON Major Modules (cont.)

- The burnup module
  - EVO: Perform in-core or out-of-core depletion calculation
- The editing module
  - EDI: Compute the reaction rates, average and condensed XS and to store this info on a file for future use
- Other modules
  - CPO: Database reconstruction module
  - INFO: Utility module
  - PSP: Graph module

DRAGON Data Structure

- MACROLIB
  - Transfer group ordered macroscopic XS between DRAGON modules
  - Can be a stand-alone structure or included into a larger structure, such as a MICROLIB structure
  - Created by the MAC:, LIB: and EDI: modules
  - Can be modified by the SHI: and EVO: modules
  - Required for the execution of the ASM: and FLU: modules
- MICROLIB
  - Transfer microscopic and macroscopic XS between DRAGON modules
  - Always include a MACROLIB structure
  - Can be a stand-alone structure or included into a larger structure, such as an EDIT structure
  - Created by the LIB: and EDI: modules
  - Can be modified by the MAC:, SHI: and EVO: modules

DRAGON Data Structure (cont.)

- GEOMETRY
  - Transfer THE GEOMETRY between DRAGON modules
  - Can be a stand-alone structure or included into a larger structure, such as another GEOMTRY structure
  - Created by the GEO: module
  - Required for the execution of the tracking modules
- TRACKING
  - Transfer the general tracking information between DRAGON modules
  - A stand-alone structure
  - Created by the tracking modules
  - Required for the execution of the ASM: module

DRAGON Data Structure (cont.)

- ASMPIJ
  - Transfer the multigroup response and CP matrices between DRAGON modules
  - A stand-alone structure
  - Created by the ASM: module
  - Required for the execution of the FLU: module
- FLUXUNK
  - Transfer the flux between DRAGON modules
  - A stand-alone structure
  - Created by the FLU: module
  - Required for the execution of the EDI: and EVO: modules

DRAGON Data Structure (cont.)

- EDITION
  - Store condensed and merged microscopic and macroscopic XS
  - A stand-alone structure but can contain MACROLIB and MICROLIB substructure
  - Created by the EDI: module
  - Required for the execution of the CPO: module
- BURNUP
  - Store burnup information
  - A stand-alone structure
  - Created by the EVO: module
  - Required for the execution of the CPO: module
- CPO
  - Store core-analysis related microscopic and macroscopic XS
  - A stand-alone structure but can contain MACROLIB and MICROLIB substructure
  - Created by the CPO: module

DRAGON Documents

- IGE-174, “A User’s Guide for DRAGON” by G. Marleau, A. Herbet, and R. Roy
- IGE-236, “DRAGON Theory Manual, Part 1” by G. Marleau
- IGE-163, IGE-163, “The CLE-2000 Tool-Box” by R. Roy
- IGE-232, “A Description of the DRAGON Data Structures” by a. Herbet, G. Marleau and R. Roy
- IGE-233, “The EXCELL Geometry Numbering Scheme in DRAGON” by G. Marleau
- RC-2621, “Procedures for Reactivity-Device Calculations Using WIMS-AECL and DRAGON” by R.S. Davis

- Part 2: DRAGON Input

DRAGON Input: General Rules

- Input file formats
  - 72 columns, free format instruction ends by ;
  - Comments * or !
  - Module and objects declarations
  - Sequence of calls to modules

    list of output objects) := GEO: (list of input objects) ::

    (data input) ;
  - END: ; statement
  - Reference: IGE-163, "The CLE-2000 Tool-Box"

DRAGON Input: General Rules (cont.)

- Data structure formats
  - LINKED_LIST — memory access
  - XSM_FILE — direct-access file
  - SEQ_BINARY — sequential binary file (tracking information mainly)
  - SEQ_ASCII — sequential ASCII file (backup purpose, platform independent format)
  - DIR_ACCESS — XS library file

DRAGON Input: General Rules (cont.)

- Working with variables
  - Variable types
    - INTEGER (signed) numbers
    - REAL (signed) decimal number with E or .
    - DOUBLE (signed) decimal number with D or .
    - STRING 72 character long, enclosed in “ ”
    - LOGICAL
  - Variable names are case sensitive

DRAGON Input: General Rules (cont.)

- Working with variables
  - Assign or Evaluate variables

REAL	*(variable names) := (value or expressions) ;*
EVALUATE	*(variable names) := (value or expressions) ;*
ECHO	*(variable names) ;*

  - Variable in data input deck
    - << . >> access the content of a variable *send*
    - >> . << put a value into a variable *recover*

DRAGON input: General Rules (cont.)

- Working with variables
  - Operations on variables
    - RPN (Reversed Polish Notation) for the calculator

      (value) (value) (operator)
    - Arithmetic operations + - * / **

      Ex. *delta := b 2 ** a c * 4. * -*
    - Unary operations *COS SQRT ABS NOT LN*

      Ex. *delta := delta SQRT*
    - Relational operations > < = <> <= + -

      Ex. *condition := a b <=*
    - Operations on STRING variables + -

DRAGON Input: Library

- Input cross sections
  - Macroscopic library
    - MAC: data input
    - EDI: DRAGON calculation
    - T16MAC: Post-process WIMS-AECL TAPE16
    - Lib: microscopic library (object input in ASM:, EXCELL:, EDI:)
  - Microscopic library
    - Library such as WIMS-AECL ENDF/B-VI…
    - Object input in LIB:, SHI:, EVO:, and EDI

DRAGON Input: Geometry

- Geometry Card
  - TUBE, TUBEX, TUBEY, TUBEZ
  - CAR1D, CAR2D, CAR3D
  - CARCEL, CARCELX, CARCELY, CARCELZ
  - HEX, HEXZ
  - HEXCEL, HEXCELZ
- Mesh subdivision
  - SPLITX, SPLITY, SPLITZ
  - SPLITR
- Boundary Conditions
  - VOID: no incoming flux
  - SYME: cell-center reflective
  - REFL: cell-edge reflective
  - TRAN: isotropic or specular periodic cell
  - ALBE, DIAG

DRAGON Input: Geometry (cont.)

- Region identification for single cell:
  - Radically outward in a cell
  - From lower to upper *x* location in a cell
  - From lower to upper *y* location in a cell
  - From lower to upper *z* location in a cell
- Region identification for assembly of cells:
  - Inside each cell as above
  - From lower to upper *x* cell location in the assembly
  - From lower to upper *y* cell location in the assembly
  - From lower to upper *z* cell location in the assembly
- PSP: Generate PostScript representation of 2D geometry

DRAGON Input: CP Integration and Tracking

- For SYME and DIAG BC, the tracking takes place over the unfolded geometry
- As many tracking angles as possible
- Tracking density must be as fine as possible
- Each region must be crossed at least once
- Sample 3D tracking input card:
  - *TRAK TISO 8 25.0*
  - 8*(8+2)/2=40 angles per half sphere
  - Density of the Integration lines is 25 per cm^2
- Verify volume and surface integration errors. EXCELL: useful print levels *EDIT n*
  - n=0 no printing
  - n=1 echo of data input and geometric information (default)
  - n=2 tracking error on volumes and surfaces
  - n=5 surface and region numbering and description, cell by cell and then global by plane in 3D

DRAGON Input: Flux Solution

- Types of flux calculation to be performed
  - TYPE N: No flux calculation
  - TYPE S: Fixed source problem
  - TYPE K: Critical K_{eff} calculation
  - TYPE B: Critical buckling calculation
- Leakage models
  - Leakage coefficient calculation
    - P0: Using a P_0 model
    - P1: Using a P_1 model
    - B0: Using a B_0 model (default)
    - B1: Using a B_1 model
  - Buckling contribution
    - PNL: Homogeneous (dafault)
    - HETE:Heterogeneous

DRAGON Input: Editing

- Energy group condensation
  - Ex: *COND 0.625* or *COND 65 89*
  - Standard 2-group condensation
- Homogenization
  - Complete homogenization: merge all regions completely
    - Ex: *MERG COMP*
  - By MIXTURES: merge regions containing the mixture numbers
    - Ex: *MERG MIX 1 1 1 1 0 1 1 1 1 1*
    - Compute a new paste with everything except mixture number 5
  - By REGIONS: merge regions to form a macro-region
    - Ex: *MERG REGI 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4 5 5 5 0 0 0 0*
    - Compute 5 new macro-regions

DRAGON Input: Editing (cont.)

- Isotropic Information
  - Isotope processing from homogenized regions and results in condensed and homogenized microscopic XS
    - Ex: *MICR ALL* all isotopes in macro-regions
    - Ex: *MICR (niso) (namiso)* isotope names are specified
- Printing Information
  - EDI: useful print levels *EDIT n*
    - n=0 no printing
    - n=1 homogenization and condensation results of the flux (default)
    - n=2 reaction rates
    - n=5 reaction rates and condensed and/or homogenized XS

DRAGON Input: Editing (cont.)

- Saving Information
  - *SAVE*

    Name='REF-CASE'+number (I4)
  - *SAVE ON (name)*

    Name =(name)+number (I4)
  - *SAVE ON (number)*

    Name='REF-CASE'+number (I4)
  - Note: number is computed as one more than the previously stored directory in EDITION data structure
- Generation of the CPO File for core analysis
  - CPO: Module
  - Single set of XS (no depletion)

    Ex: *COMPO :=CPO: EDITION :: STEP 'REF_CASE 1' NAME 'REF_CASE 1'*
  - Depletion calculation, multiple sets of XS (depletion calculation)

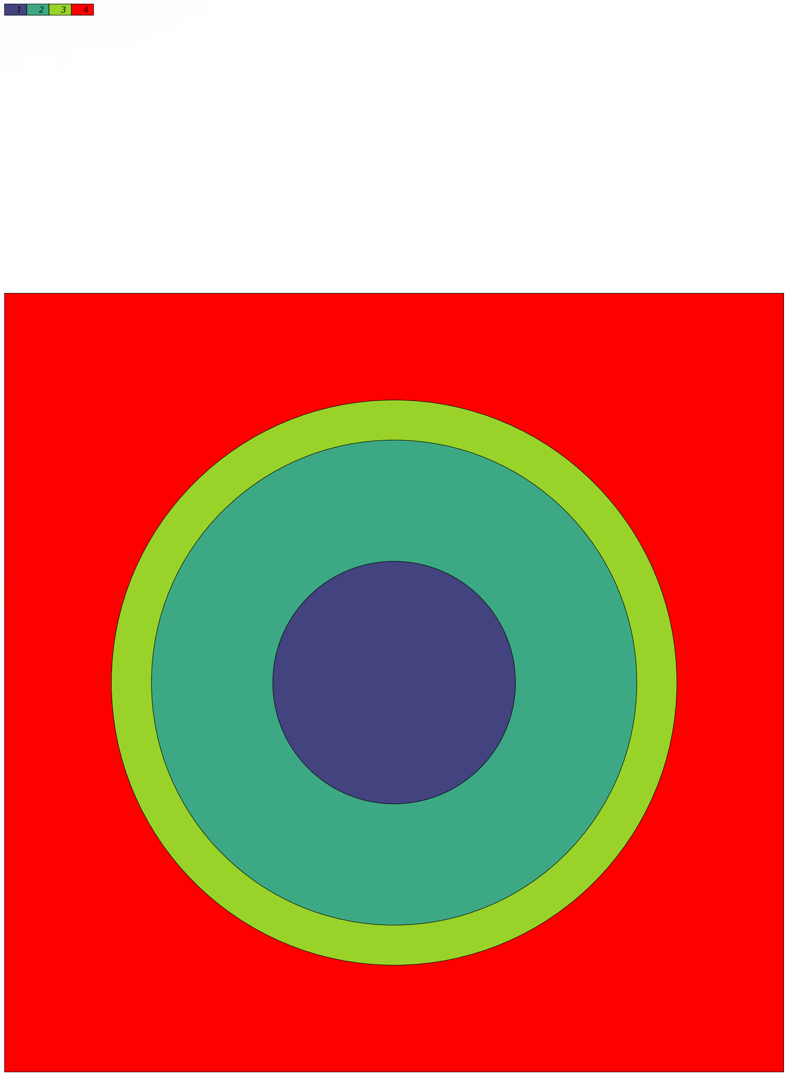
    Ex: *COMPO :=CPO: EDITION BURNUP :: BURNUP 'REF_CASE' NAME COMPO*

Sample DRAGON Inputs and Outputs

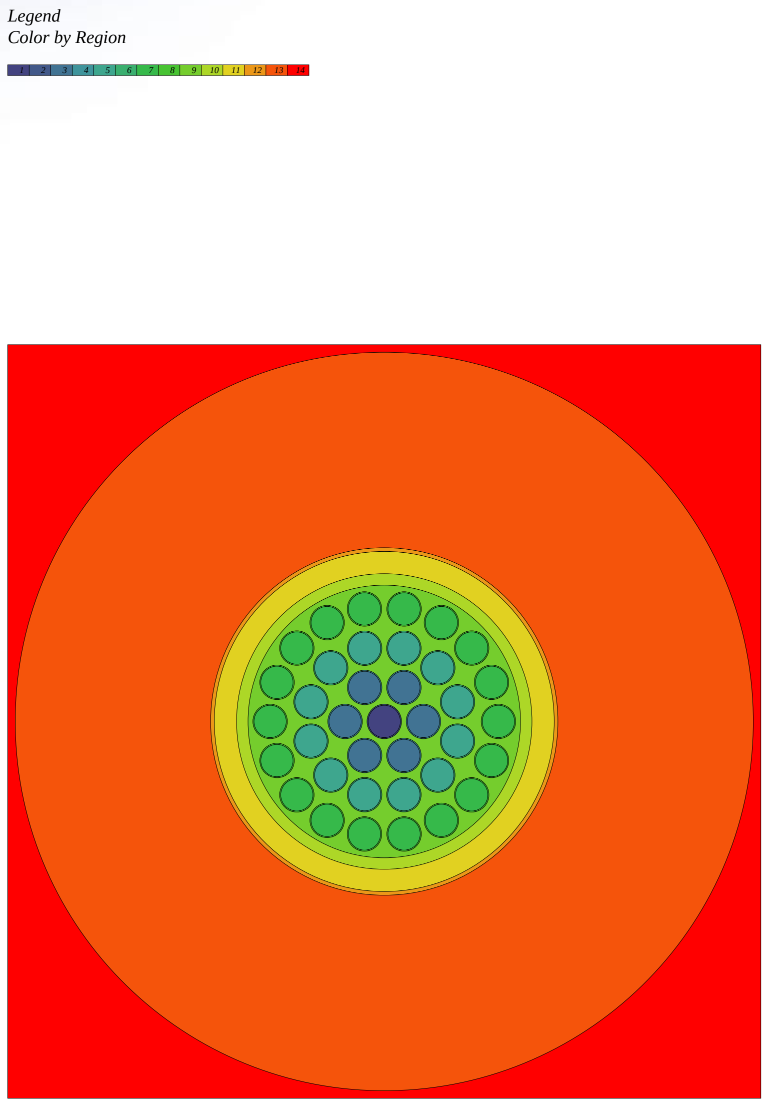
- Test cases
  - TCW601: 1D Mosteller benchmark problem
  - TCW606: CANDU-6 supercell model
- Sample case for the ACR device
  - Geometry: geo
  - Cross section: lib
  - Flux calculation: cal_ref, cal_in, cal_out
  - Homogenization: total

DRAGON Model for TCW601

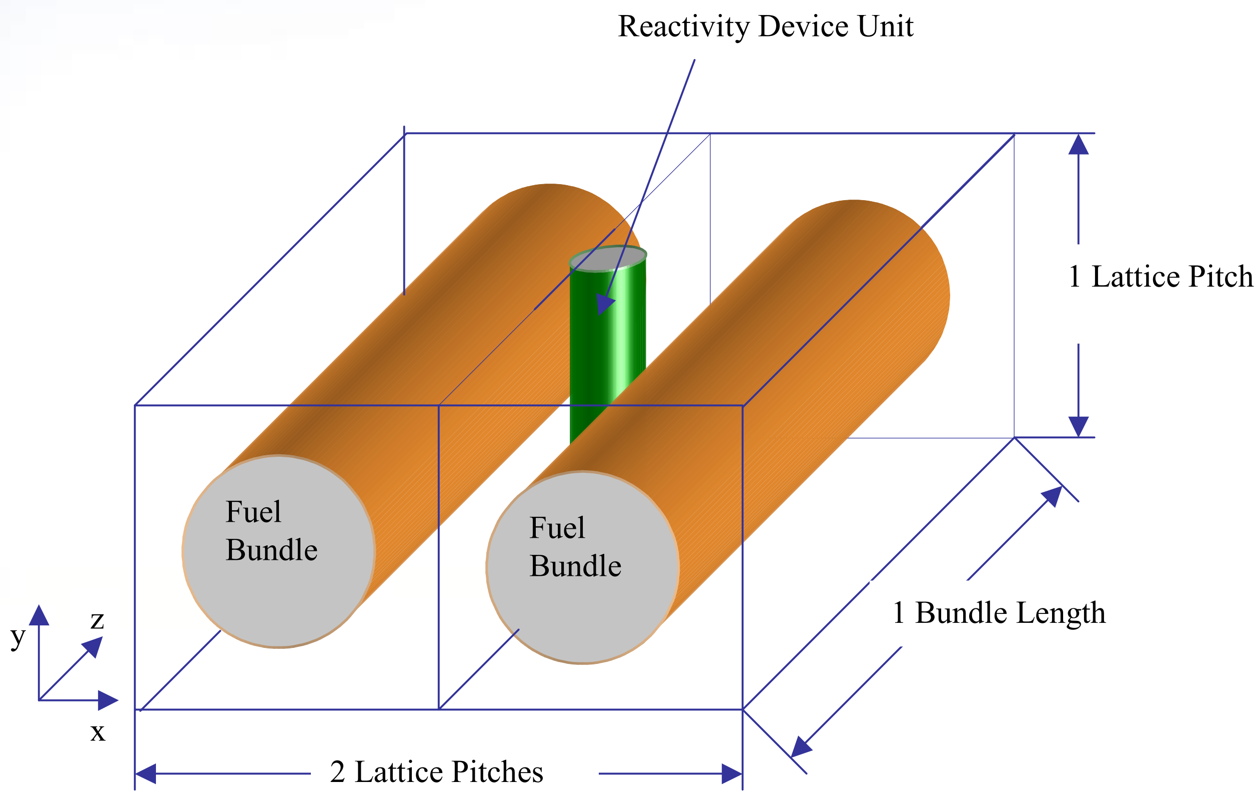
Legend
Color by Region



DRAGON Model for TCW606 (2D Cell)



DRAGON Model for TCW606 (3D Supercell)



- Part 3: DRAGON Execution

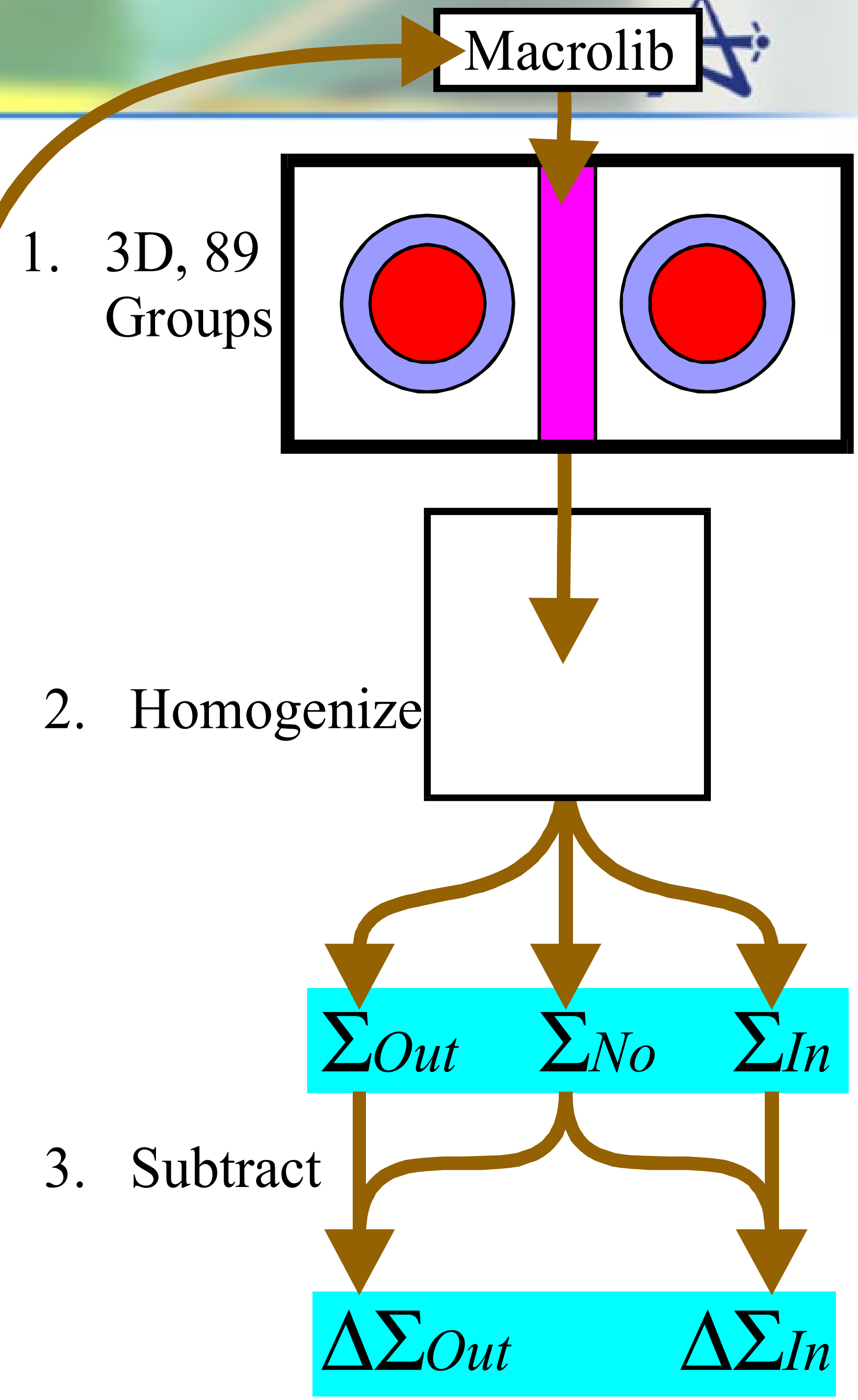
DRAGON Methods

- DRAGON represents both the fuel channel and the reactivity device as sets of concentric annuli or rectangle in 3-D, hence it requires homogenized multigroup macroscopic XS to represent the materials in the fuel channels and in the reactivity devices.
- Two methods identified
  - All-DRAGON method: DRAGON performs both 2-D lattice-cell and 3-D supercell calculations
  - Side-step method: DRAGON performs 3-D supercell calculations while the 2-D lattice-cell calculations are performed with WIMS-AECL

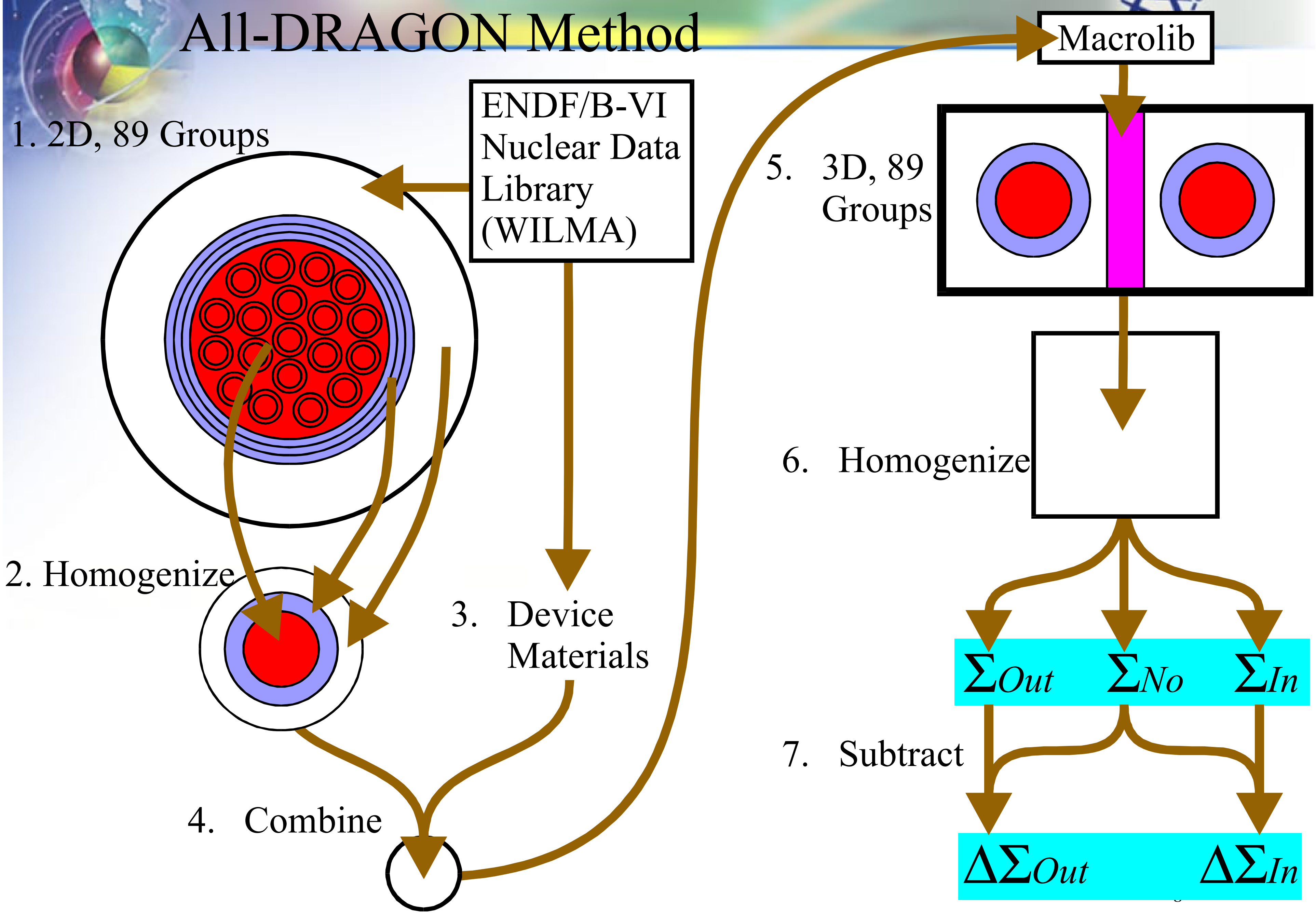
Two Methods

- All-DRAGON
- Side-Step

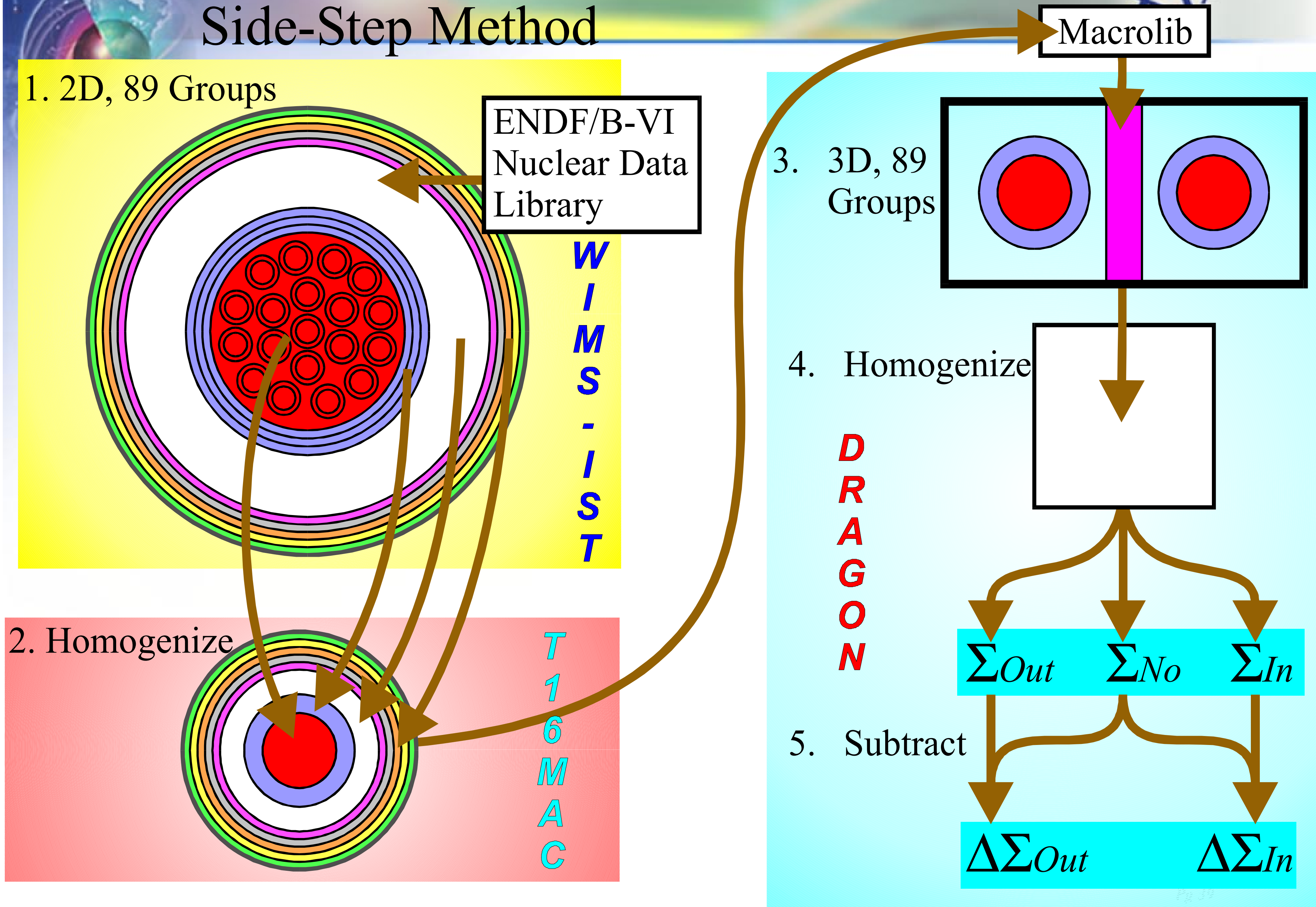
They differ in the manner in which they create the necessary homogenized cross sections



All-DRAGON Method



Side-Step Method



DRAGON Side-Step Method: Advantages

- Qualified method for reactivity-device calculations
- No extra effort is required to prepare the corresponding libraries with the same physical information in a format that DRAGON can read
- No extra effort is required to set up the 2-D lattice-cell calculations with DRAGON, which duplicates the work that has been done with WIMS-AECL. In addition, DRAGON and WIMS-AECL 2-D lattice-cell results are not necessarily identical
- Since the incremental XS are to be added to the device-free lattice-cell cross sections calculated with WIMS-AECL, it is more consistent that the multi-group macroscopic XS representing the materials in the fuel channels and in the reactivity devices are produced by homogenization from WIMS-AECL 2-D lattice-cell calculations.

DRAGON Side-Step Method: Models

Side-Step Method	WIMS 2D Lattice Cell	DRAGON 3D Supercell
Library	89 Group ACR Library	
Geometry	2D Cluster	3D (2LP x 1LP x 1BL)
Self-Shielding	CP Technique	
Transport calculation	CP Technique (89 groups)	
Flux Solution	No leakage	

DRAGON Side-Step Method: Procedures

- WIMS-AECL 2-D fuel-cell transport calculations in 89 groups
- Homogenization of the fuel-cladding-coolant region and production of the corresponding 89-group macroscopic XS
- WIMS-AECL 2-D device-cell transport calculations in 89 groups
- Homogenization of the reactivity devices, if necessary, and production of the corresponding 89-group macroscopic XS
- DRAGON 3-D supercell transport calculations, with and without the reactivity devices, in 89 group groups
- Calculation of 2-energy-group incremental cross sections using the difference between the 3-D results with and without the device

Managing a DRAGON Execution with the Side-Step Method

- Generate 89-group macroscopic XS for the fuel-cladding-coolant region on PC
  - Run WIMS-AECL input "Acr_fuel" on PC and produce the TAPE16 file "temp1.t16" for the sequential T16MAC run
  - Run T16MAC input "t16_fuel" on PC and produce an ASCII file "fuel89g" for the sequential DRAGON run
- Generate 89-group macroscopic XS for the reactivity devices on PC
  - Run WIMS-AECL input "Acr_dev" on PC and produce the TAPE16 file "temp1.t16" for the sequential T16MAC run
  - Run T16MAC input "t16_fuel" on PC and produce an ASCII file "dev89g" for the sequential DRAGON run

Managing a DRAGON Execution with the Side-Step Method (cont.)

- Copy the ASCII files “fuel89g” and “dev89g” from PC to HP Unix account
- Run DRAGON on HP and produce the DRAGON CPO file
- Post-processing the DRAGON CPO file with “READ_CPO” utility on HP and generate 2-group incremental XS for use in RFSP

- Part 4: DRAGON Interface

Interface with WIMS-AECL

PROTECTED-Proprietary

Interface with WIMS-AECL (cont.)

PROTECTED-Proprietary

Interface with WIMS-AECL (cont.)

PROTECTED-Proprietary

Materials Defined in theWIMS-AECL Model

PROTECTED-Proprietary

The Cross-Section of the ACR SOR Unit

PROTECTED-Proprietary

3-D Supercell Geometry with DRAGON

PROTECTED-Proprietary

Interface with RFSP-IST

Interface with RFSP-IST (cont.)

PROTECTED-Proprietary