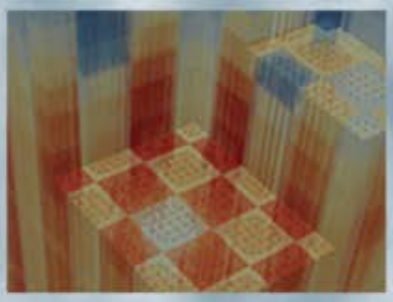
CASL-U-2015-0067-000

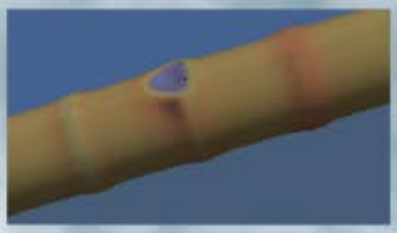
Virtual Environment for Reactor Applications (VERA) Workshop

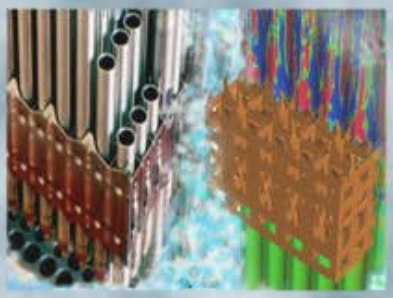
Session 2: Hands on Training

Rose Montgomery
The Tennessee Valley Authority

April 1, 2015







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The American Nuclear Society
ANFM Topical Meeting presents

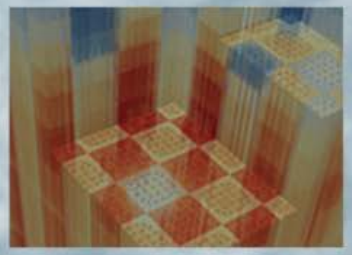
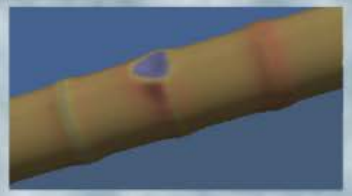
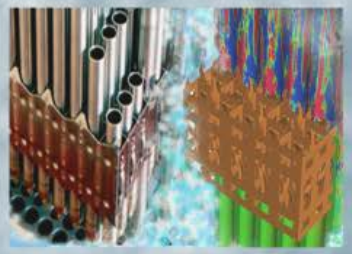
A DOE Energy Innovation Hub

Virtual Environment for Reactor Applications (VERA)

Hands-On Training

April 1, 2015
Hilton Head, SC

Please check in to receive your student packet and RSA token to log onto the computers.

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WELCOME

- Logistics
- Introductions
  - CASL Staff
  - Attendees
- Training Packages

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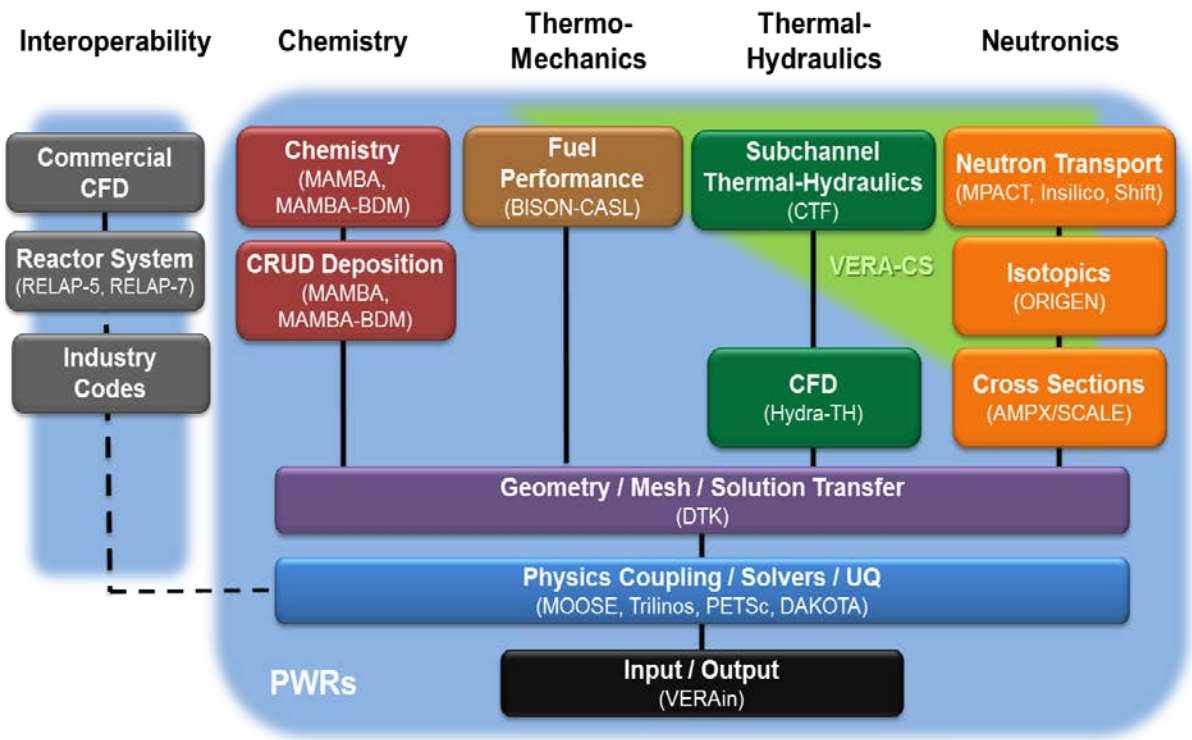
VERA Physics Components

- Method of Characteristics (MOC) neutronics tool
- Monte Carlo neutronics tool
- Subchannel thermal-hydraulics tool
- Fuel performance tool
- Computational fluid dynamics tool
- Chemistry tool



Today's workshop is focused on the fundamentals of running the VERA Core Simulator, including coupled MOC and subchannel thermal-hydraulics

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Versions & Platforms

- VERA is designed to operate on Linux, and has been successfully built on:
  - Redhat Enterprise
  - SUSE
  - Ubuntu
  - CENTos
  - Fedora
- Periodically released

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Availability

- VERA is currently authorized for government use only
  - Commercial / non-commercial licensing is expected to be available in 2015
  - Educational licensing is expected to be available in 2015
    - Educational course modules are being deployed at selected U.S. universities and will be expanded to additional universities by the end of 2015
- Approval for use is restricted based on U.S. Export Control regulations

Learn more about U.S. export control here:
http://www.state.gov/strategictrade/overview/

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Contact Info

- Website:
  - www.casl.gov
- VERA questions:
  - support@casl.gov
- Bugs, enhancement requests:
  - support@casl.gov
- CASL / VERA News:
  - To subscribe, send email to CASL-update@casl.gov with “subscribe” in the subject.
- Join the VERA Working Group
  - A User Portal website is being developed
  - Look for an invitation later this year

Objectives for Today's Workshop

- Learn about the basic VERA core simulator inputs
  - Block structure
  - Geometry and symmetry options
  - Specifying core conditions and depletion steps
  - Turn coupled subchannel thermal-hydraulics "on" and "off"
- Get hands-on practice modifying inputs and submitting jobs
  - Experience using smaller machines and high performance machines
- Locate the output of interest in VERA's output files
- Experience some post-processing visualization options

More in-depth tutorials will be available in the Fall

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VERA Quick Start

- Introduction to VERA's common Input
- 4 Hands-on tutorials
  - Neutronics simulation of a 2D fuel rod cell
  - Neutronics simulation of a 2D fuel rod lattice
  - Neutronics simulation of a single fuel assembly (3D) at hot full power with thermal-hydraulic feedback and depletion
  - Neutronics simulation of a 3D small reactor core using quarter-core symmetry
- Demonstration
  - Setup, execution and results for a 3D core with thermal-hydraulic feedback and depletion

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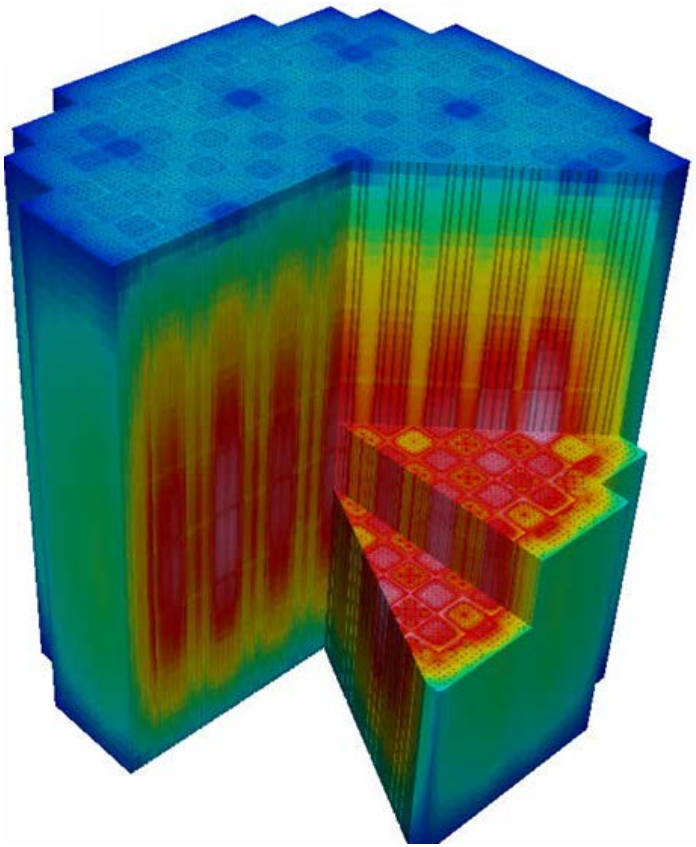
Today's Workshop Problems

- Provide the foundation for you to execute a full core problem
- Covers:
  - VERA input structure and typical inputs for the core simulator for a Westinghouse 4-loop NSSS with 17x17 fuel
  - Basic coupled neutronics and subchannel thermal-hydraulics cases
  - Code execution on local machines and High Performance Computers



A single example problem, starting with building a pin cell and progressing to the full core simulation

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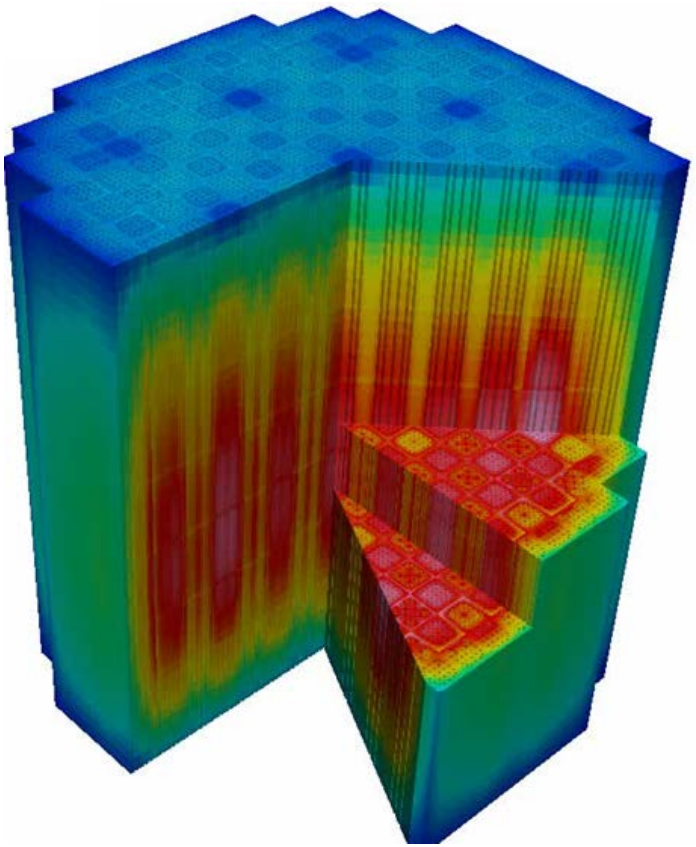
Today's Workshop Problems

- Doesn't provide:
  - In depth training of VERA and VERA methodology
  - In depth descriptions of each input keyword
  - Discussions on the numerical approach and convergence options
  - Practice running VERA's fuel performance, chemistry and CFD tools
  - Training on the post-processing software
    - VERA currently relies on non-CASL post-processing tools such as VisIT and ParaView.
    - Future VERA releases may have a post-processing tool



Four hours is just enough time to get started!

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VERA Quick Start

- *In-class hands-on cases are limited in both size and fidelity based on time available and classroom computing resources*
  - The single assembly and small core examples were computed at a much coarser resolution with looser convergence criteria to allow faster run time
  - Accuracy was sacrificed for run time
- Tutorials to be published on the CASL website
- More advanced courses to be developed in CASL phase 2 (2015 to 2020)
  - If you'd like notifications, please subscribe at CASL-update@casl.gov

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VERA User Interface

- The VERA Common Input [VERAin] products intuitive and consistent input to all of the VERA Core Simulator components
  - VERAin is used to run the VERA physics toolset, with the exception of the CFD tool
  - VERAin generates XML files from the User's ASCII input deck
  - The VERAin Users Manual is provided in your documentation package and can be found in your VERA build in the /doc subdirectory

```
crd_map
  1
  - -
  1 - 1
  - - - 1
  1 - - - 1
  - 1 - 1 - -
  1 - 1 - 1 -
  - - - -

crd_bank
  D  -  A  -  D  -  C  -
  -  -  -  -  - SB  -  -
  A  -  C  -  -  -  B  -
  -  -  -  A  - SC  -  -
  D  -  -  -  D  - SA
  - SB  - SD  -  -  -
  C  -  B  - SA  -
  -  -  -  -

[ASSEMBLY]
  title "Westinghouse 17x17"
  npin 17
  ppitch 1.260

  fuel U21 10.257 94.5 / 2.110
  fuel U26 10.257 94.5 / 2.619
  fuel U31 10.257 94.5 / 3.100

  cell 1     0.4096 0.418 0.475 / U21 he zirc4
  cell 2     0.4096 0.418 0.475 / U26 he zirc4
  cell 3     0.4096 0.418 0.475 / U31 he zirc4
  cell 4            0.561 0.602 / mod    zirc4
  cell 5            0.418 0.475 /     he zirc4
  cell 6                  0.475 /        zirc4
  cell 7                  0.475 /        mod

  lattice LAT21
       4
       1 1
       1 1 1
       4 1 1 4
       1 1 1 1 1
       1 1 1 1 1 4
       4 1 1 4 1 1 1
       1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1

  lattice LAT26
       4
       2 2
       2 2 2
       4 2 2 4
       2 2 2 2 2
       2 2 2 2 2 4
       4 2 2 4 2 2 2
       2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2
```

VERAin is the primary User Interface with VERA core simulator

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Standard Input Deck

The VERAin Standard Input Deck is divided into several [BLOCKS]:

STATE

- Describes core operating parameters at a particular point in time

CORE

- Describes core size and layout of assemblies, rods, inserts, and detectors

Define materials globally in this block

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Standard Input Deck

The VERAin Standard Input Deck is divided into several [BLOCKS]:

ASSEMBLY

- Describes each unique fuel assembly in the core design

INSERT

- Contains geometry and physical description of burnable poisons (BPs) and/or thimble plugs

CONTROL

- Contains geometry and physical description of control rod assemblies

DETECTOR

- Contains geometry and physical description of detector strings

Define materials locally in these blocks

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Standard Input Deck

The VERAin Standard Input Deck is divided into several [BLOCKS]:

EDITS

- Specifies axial levels at which power and/or neutronics-T/H coupling will be solved

COUPLING

- Defines the convergence parameters for coupling the different physics codes

MPACT

- Transport code

COBRATF

- Subchannel thermal-hydraulics code

Each tutorial focuses on learning the minimum information contained in each [BLOCK]

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A typical input deck

- Watts Bar full core, cycle 1 depletion

The Quick Start Tutorials will only touch the surface of the capabilities available in VERA

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BREAK

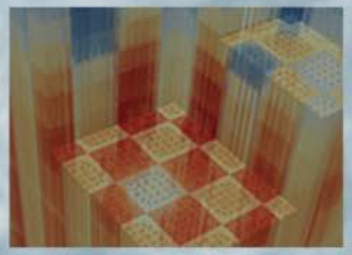
Is everyone logged on?

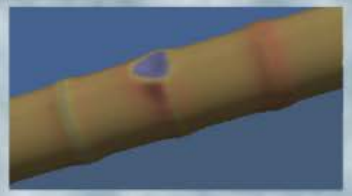
Using the directions printed on your RSA token, connect to Leza's wireless router and ssh onto Leza for QST-1 and QST-2

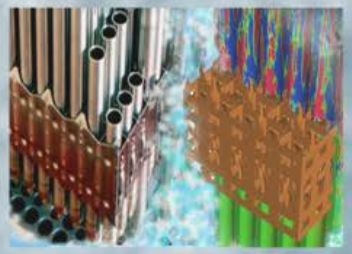
Lise Meitner (1878 – 1968)
Photo: the Granger Collection, NY

When Lise Meitner finished school at age 14, she was barred from higher education, as were all girls in Austria. But, inspired by the discoveries of William Röntgen and Henri Becquerel, she was determined to study radioactivity. When she turned 21, women were finally allowed into Austrian universities. Two years of tutoring preceded her enrollment at the University of Vienna; there she excelled in math and physics and earned her doctorate in 1906. She wrote to Marie Curie, but there was no room for her in the Paris lab and so Meitner made her way to Berlin. There she collaborated with Otto Hahn on the study of radioactive elements, but as an Austrian Jewish woman (all three qualities were strikes against her), she was excluded from the main labs and lectures and allowed to work only in the basement. In 1912, the pair moved to a new university and Meitner had better lab facilities. Though their partnership was split up physically when she was forced to flee Nazi Germany in 1938, they continued to collaborate. Meitner continued her work in Sweden and after Hahn discovered that uranium atoms were split when bombarded with neutrons, she calculated the energy released in the reaction and named the phenomenon "nuclear fission." The discovery—which eventually led to the atomic bomb ("You must not blame scientists for the use to which war technicians have put our discoveries," Meitner would say in 1945)—won Hahn the Nobel Prize in 1944. Meitner, overlooked by the Nobel committee, refused to return to Germany after the war and continued her atomic research in Stockholm into her 80s.

Taken entirely from: http://www.smithsonianmag.com/science-nature/ten-historic-female-scientists-you-should-know-84028788/#zifPE7kBYIgGG00w.99
Read more at: http://en.wikipedia.org/wiki/Leza_Meitner







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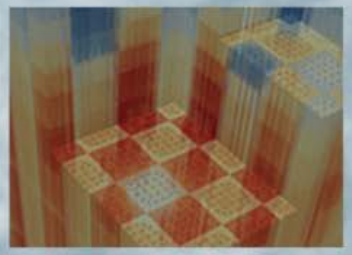
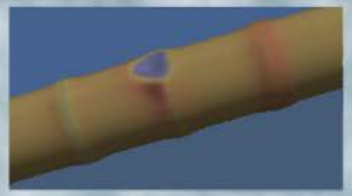
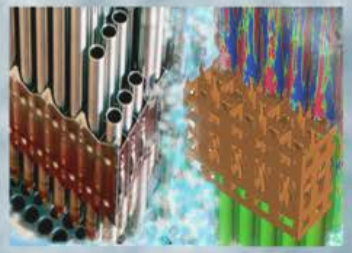


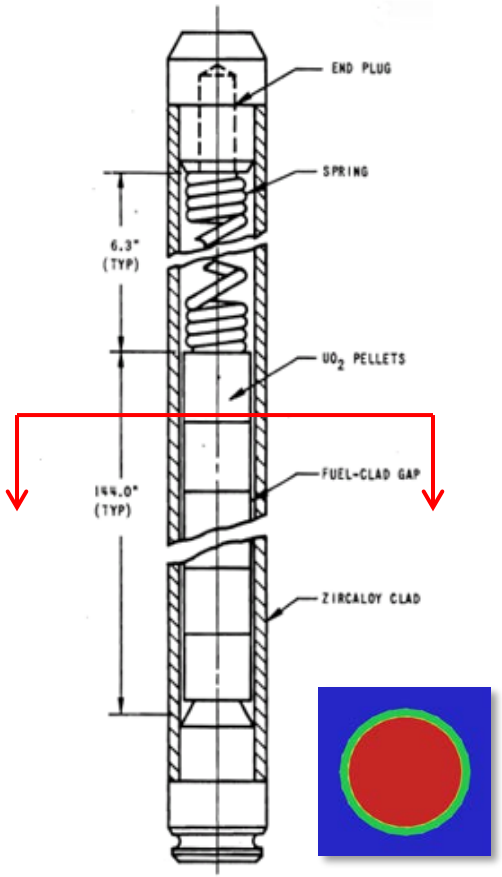




Quick Start Tutorial #1
Neutronics analysis of a 2D fuel rod cell

Quick Start Tutorial # 1
2D Fuel Rod Cell

- Simple two-dimensional fuel rod cell
  - UO_2 fuel pellet
  - Zircaloy-4 cladding
  - Pressurized water moderator with soluble boron
  - Pellet-clad gap with helium backfill
- Eigenvalue problem typical of PWR reactor analyses
- Beginning-of-life (BOL) conditions
- Hot zero power



Tutorial #1 Fuel Rod Arrangement

Exercise objective: learn the basic steps associated with running VERA

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Files you will find in the qst-1 folder

Open the tutorial #1 input deck:
cd *qst-1*
vi *qst-1.inp*

- qst-1.inp - the input for this case
- run-qst-1 - the script that runs this case
- qst-1-mpact-params – a file that includes the MPACT parameters to run this case
  - we won't be talking about these parameters in this tutorial

Open qst-1 to modify the inputs for the case

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QST#1
Edit Input Deck

```
[CASEID]
  title 'CASL AMA Benchmark Problem 1A - Pin Cell- Public'

[STATE]
  title    QST-1
  power    0.0
  tinlet   800 K
  tfuel    900 K
  modden   0.743          ! g/cc
  boron    700            ! ppm
  sym      qtr
  feedback off

[CORE]
  size   1
  apitch 1.26
  rated  0.01 0.01
  height 1.0

  core_shape
    1

  assm_map
    ASSY1

  bc_rad reflecting
  bc_top reflecting
  bc_bot reflecting

[ASSEMBLY]
  title "pin cell"
  npin 1
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell PIN1 0.4096 0.418 0.475 / U31 he zirc4

  lattice LAT1
     PIN1

  axial ASSY1 0.0 LAT1 1.0

[MPACT]
  include qst-1-mpact-params
```

STATE

- [STATE] block describes reactor core operating parameters (statepoint values) at a particular point in time. Can change during run

QST#1
Input - [STATE]

Input Parameter	Description
title	Title for the simulation
power	operating power (percent of rated power)
tinlet	inlet temperature (F, K, or C)
tfuel	fixed fuel temperature (F, K, or C)
modden	fixed moderator density (g/cc)
boron	soluble boron concentration (ppm)
sym	core fraction to run problem in (full or qtr)
feedback	flag for T/H feedback (on or off)

```
[STATE]
  title    QST-1
  power    0.0
  tinlet   800 K
  tfuel    900 K
  modden   0.743          ! g/cc
  boron    700            ! ppm
  sym      qtr
  feedback off
```

change to 565 K

change to 565 K

change to 1300

Refer to your vi command summary for help with editing; don't forget to save your edited file :x

VERA uses fixed metric units, with the exception of tinlet and tfuel

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QST#1
Running the VERA Core Simulator

- To run the VERA core simulator using VERAin, the user typically prepares and launches a run script.
- The first part of the script usually provides the locations of the code executables and necessary libraries, as well as specifying the number of cores to be used to run the job.
- The commands that must be executed include parsing the input for the various physics to be included in the simulation and then launching the physics codes once the input has been parsed
- The MPACT.ini initialization file is specified for use in the run script with the "--init" option

```
#!/bin/bash

cd /home/user

case=QST-1
cores=8

# set executables
parser=/home/tet/VERA.base/VERA/……/react2xml.pl
exe=/home/tet/VERA.base/Builds/……/MPACT.exe
export MPACT_DATA=/home/tet/tools/……/test_data
pwd

date
echo case = $case
echo input = $case.inp
echo executable = $exe
echo data = $MPACT_DATA
echo


# parse input
rm $case.xml
echo "=============================================="
echo "   Parsing VERA input"
echo "=============================================="
perl $parser --init $case.inp $case.xml
ls -l $case.xml
date

# run MPACT
echo "=============================================="
echo "   Running MPACT Job on $cores cores"
echo "=============================================="
mpirun -n $cores $exe $case.xml
date
```

These steps can be done manually (line by line) without a run script

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QST#1
Run Scripting

Calls the initialization file

parse input

```
perl   $parser.pl   --init   $case.inp   $case.xml
```

run Neutronics

```
aprun   -n   $cores   $MPACT.exe   $case.xml
```

aprun on Titan;
mpirun on Leza

Note that for this case we are running neutronics without using the coupled thermal-hydraulics option, since the script doesn't call CTF

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Job Submission QST#1

Running the case on Leza

Your run script should look like this:

```
#!/bin/bash
cd /home/user

# load development environment
source /projects/vera/gcc-4.6.1/load_dev_env.sh

case=qst-1
cores=2

# set executables
parser=/home/tet/VERA.base/VERA/..../react2xml.pl
exe=/home/tet/VERA.base/Builds/..../MPACT.exe
export MPACT_DATA=/home/tet/tools/..../test_data
pwd

date
echo case = $case
echo input = $case.inp
echo executable = $exe
echo data = $MPACT_DATA
echo


# parse input
rm $case.xml
echo "=============================================="
echo "   Parsing VERA input"
echo "=============================================="
perl $parser --init $case.inp $case.xml
ls -l $case.xml
date

# run neutronics
echo "=============================================="
echo "   Running Job on $cores cores"
echo "=============================================="
mpirun -n $cores $exe $case.xml
date
```

Type: *./run-qst-1*

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VERA processing & output files

- $case.xml – the VERAIn parsed input to the codes
- $case.log – a record of the information echoed to the screen during the run
- $case.out – a human-readable output file
- $case.h5 – a standard hdf5 formatted file containing inputs and outputs
- $case.silo – a file generated from the h5 file that is readable by VisIT or ParaView for visualization

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QST#1
Viewing Results

To view simulation output,

type: *cat qst-1.log*;

<u>or</u>

For full output that includes pin powers, XS data, materials, etc.,

type: *cat qst-1.out*

```
000:00.01 Processing Input...
000:00.14 Processing XS Libraries...
000:00.79 Generating Materials...
000:00.81 Generating Reactor Geometry...
000:00.81 Generating Reactor Mesh...
000:00.84 Initializing Parallel Environment...
000:00.96 Setting up angular quadrature...
000:00.96 Initializing mesh...
000:00.97 Generating Input Edits...
000:01.06 Initializing Base MOC Sweeper...
              Setting up modular rays...
              Performing ray tracing...
              Setting up long rays...
              Allocating base solution variables...
              Allocating solution variables...
000:01.07 Initializing Multi-group Fixed Source Solver...
000:01.08 Initializing Eigenvalue Solver...
              Adding eigenvalue accelerator...
               -CMFD acceleration is being used (MG LS, Node-Major)
                    ...with P0 boundary update
                    ...not using angle decomp processors
000:01.08 Initializing Feedback Solver...
000:01.08 Initializing MultiState Solver...
000:01.08 Calculating Equivalence XS...
          Solving Subgroup FSP...
          Group  10 Cat  1 92238    57 6.0173E-07
          Group  10 Cat  2 92235    79 9.6357E-07
          Group  10 Cat  3 40091    73 7.7760E-07
                      :
                      :
                      :
          Group  26 Cat  2 92235    77 8.6730E-07
          Group  26 Cat  3 40091    71 9.7891E-07
          Group  26 Cat  4 72177    35 7.3579E-07
000:02.12 Solving State 1/1...
000:02.17 Using TCP0 in All Regions...
000:02.17 Performing Eigenvalue Calculation...
000:02.17      iter    keff      norm_keff     norm_fissrc
000:02.17         0  1.0000000 1.000000E-06 1.000000E-06
          MG-CMFD    2     4    1.1860684   1.564463E-11
          1G-INNER   1         94           1.449512E+00
000:02.25         1  1.1860684 1.860684E-01 1.411213E-02
          MG-CMFD    2     7    1.1882253   6.589541E-12
          1G-INNER   1         94           7.164976E-02
000:02.30         2  1.1882253 2.156862E-03 7.930201E-04
                      :
                      :
                      :
          MG-CMFD    2     7    1.1862059   9.541049E-12
          1G-INNER   1         94           2.604590E-04
000:03.99        32  1.1862059 2.187175E-05 3.241345E-06
          MG-CMFD    2     7    1.1862057   9.538489E-12
          1G-INNER   1         94           8.940696E-05
000:04.05        33  1.1862057 1.723222E-07 6.428715E-07
000:04.05 Convergence criteria satisfied
000:04.06 Finished
```

Residuals of the self-shielding equivalence XS calculation

Eigenvalue iterations

keff = 1.1862057

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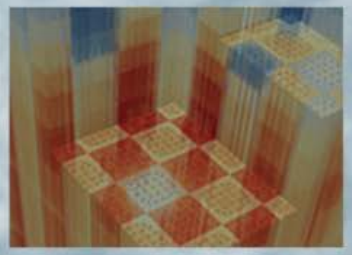
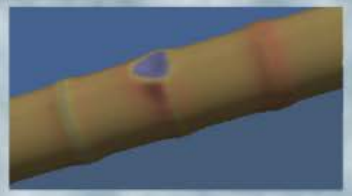
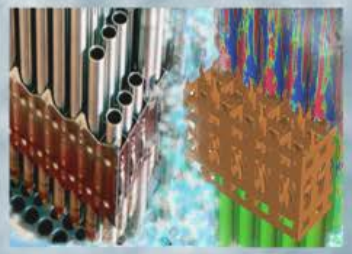


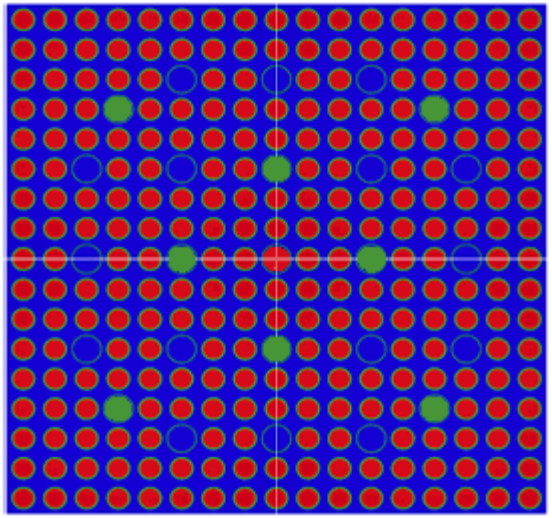


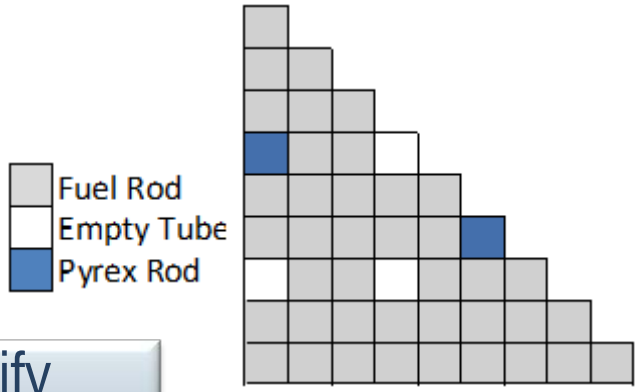


Quick Start Tutorial #2
Neutronics analysis of a 2D fuel lattice

Quick Start Tutorial # 2
2D Fuel Lattice

- Simple two-dimensional array of PWR fuel rods
  - Zircaloy-4 cladding
  - Pressurized water moderator with soluble boron
  - Pellet-clad gap with helium backfill
  - Beginning-of-life (BOL) conditions
  - Hot full power
  - Pyrex burnable absorbers
- Results permit comparison of the normalized fission reaction rate distribution among the fuel rods





QST#2 1/8th symmetry fuel lattice

Exercise objective: learn how to specify assembly lattices and to run using symmetric boundary conditions

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Files you will find in the qst-2 folder

Open the tutorial #2 input deck:
cd *../qst-2*
vi *qst-2.inp*

- qst-2.inp - the input for this case
- run-qst-2 - the script that runs this case
- qst-2-mpact-params – a file that includes the MPACT parameters to run this case
  - we won't be talking about these parameters in this tutorial

Open qst-2.inp to modify the inputs for the case

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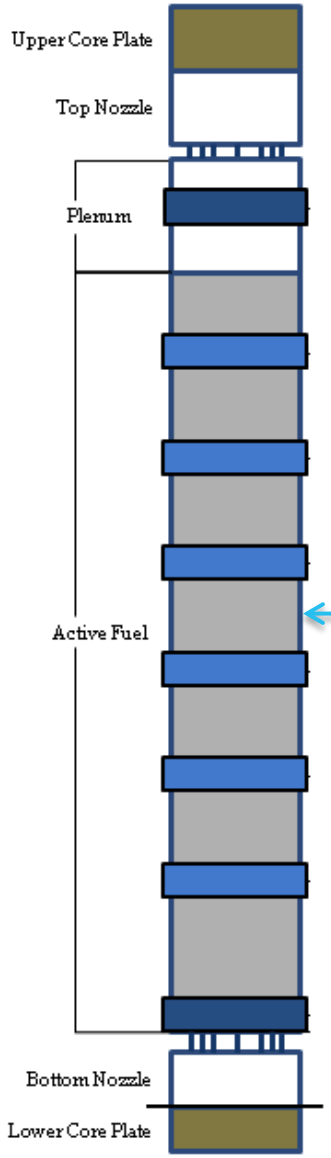
QST#2 Input

ASSEMBLY

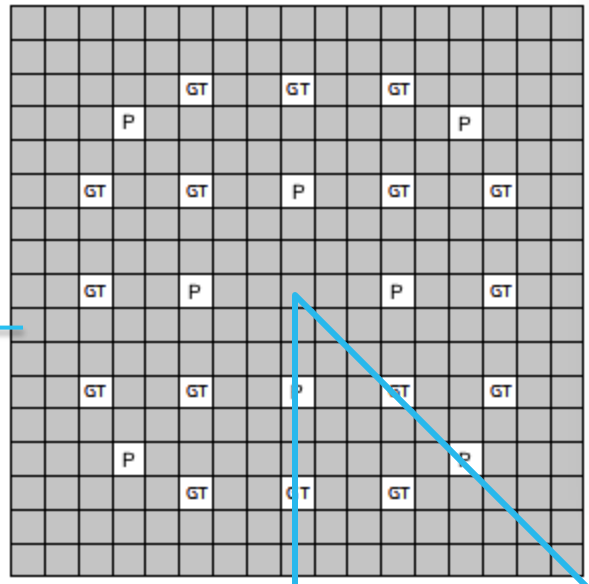
- [ASSEMBLY] block contains the geometry and physical description of the nuclear fuel assemblies.

```
[STATE]
  title    QST-2
  power    0.0
  tinlet   565 K
  tfuel    565 K
  modden   0.743       ! g/cc
  boron    1300        ! ppm
  sym      full
  feedback off

[CORE]
  size   1
  apitch 21.50
  height 1.0
  rated  0.01 0.01

  core_shape
    1

  assm_map
    ASSY

  insert_map
    PY

  bc_rad reflecting
  bc_top reflecting
  bc_bot reflecting

[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 2        0.561 0.602 /    mod zirc4

  lattice LAT
    1
    1 1
    1 1 1
    7 1 1 7
    1 1 1 1 1
    1 1 1 1 1 7
    7 1 1 7 1 1 1
    1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1

  axial ASSY 0.0 LAT 1.0

[INSERT]
  title "Pyrex"
  npin 17
  mat pyrex     2.34249   b-10   6.81945e-03
                          b-11   6.81945e-03
                          o-16   5.3500e-1
                          na-23  4.1e-2
                          al-27 1e-2
                          si-00 3.77e-1

  cell 1  0.214 0.231 0.241 0.427 0.437 0.484 / he ss he b4c he ss

  rodmap  LAT-PY
    -
    - -
    - - -
    1 - - -
    - - - - -
    - - - - - 1
    - - - - - - -
    - - - - - - - -
    - - - - - - - - -

  axial PY   0.0 LAT-PY  1.0

[MPACT]
  include qst-2-mpact-params
```

QST#2 Input – [ASSEMBLY]



For the 2D lattice, you will describe the mid-plane of the fuel rod lattice

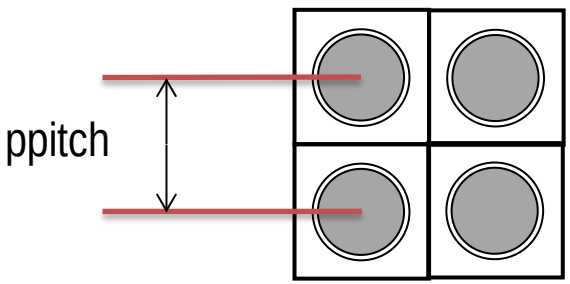



```
[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 2        0.561 0.602 /    mod zirc4

  lattice LAT
    1
    1 1
    1 1 1
    7 1 1 7
    1 1 1 1 1
    1 1 1 1 1 7
    7 1 1 7 1 1 1
    1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1

  axial ASSY 0.0 LAT 1.0
```

We will take advantage of symmetry and only model 1/8th of the lattice for this exercise; other allowed symmetry is 1/4 lattice or full lattice

QST#2
Input – [ASSEMBLY]

npin	17	number of rods along the edge of an assembly
ppitch	1.26	cell pitch (cm)




```
[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 2        0.561 0.602 /    mod zirc4

  lattice LAT
    1
    1 1
    1 1 1
    7 1 1 7
    1 1 1 1 1
    1 1 1 1 1 7
    7 1 1 7 1 1 1
    1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1

  axial ASSY 0.0 LAT 1.0
```

QST#2
Input – Local Materials

Define the fuel material and enrichment:

fuel	U31	10.257	94.5	/	3.1
	user defined fuel name	density (g/cc)	% of theoretical density		enrichment

```
[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 2        0.561 0.602 /    mod zirc4

  lattice LAT
    1
    1 1
    1 1 1
    7 1 1 7
    1 1 1 1 1
    1 1 1 1 1 7
    7 1 1 7 1 1 1
    1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1

  axial ASSY 0.0 LAT 1.0
```

ASSEMBLY

- Describes each unique fuel assembly in the core design

Define materials locally in these blocks

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QST#2
Input – [ASSEMBLY]

cell	1	0.4096	0.418	0.475	/	U31	he	zirc4
cell	7		0.561	0.602	/		mod	zirc4

user defined cell name

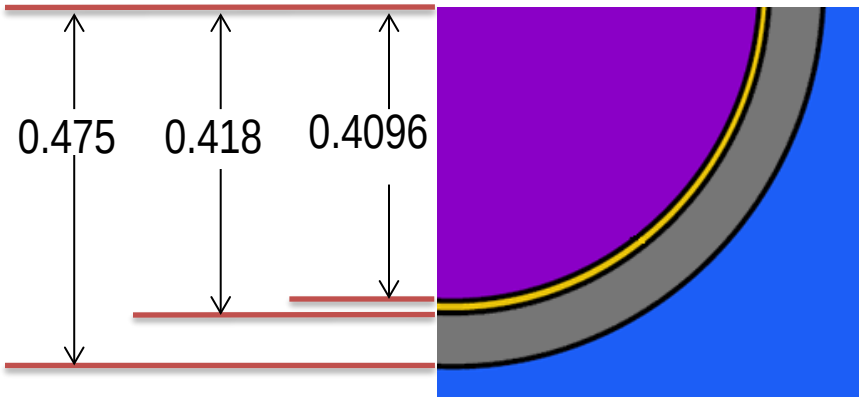
radii for each concentric cell (or "ring") (cm)

materials composing each ring

```
[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 7        0.561 0.602 /    mod zirc4
```



Create a new guide thimble cell 2 having an inner and outer radius of 0.561 and 0.602cm respectively

Refer to your vi command summary for help with editing; don't save yet, we have more edits to do!

QST#2
Input – [ASSEMBLY]

To define the lattice, each location in the array is given a cell type

Lattice LAT

```
1
1 1
1 1 1
2 1 1 2
1 1 1 1 1
1 1 1 1 1 2
2 1 1 2 1 1 1
1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1
```

cell 2 guide tube

cell 1 fuel

```
[ASSEMBLY]
  npin   17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1 0.4096 0.418 0.475 / U31 he zirc4
  cell 2        0.561 0.602 /    mod zirc4

  lattice LAT
    1
    1 1
    1 1 1
    7 1 1 7
    1 1 1 1 1
    1 1 1 1 1 7
    7 1 1 7 1 1 1
    1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1

  axial ASSY 0.0 LAT 1.0
```

Two cell types are used in our 1/8th symmetry lattice:

cell	1	fuel
cell	2	guide tube

Refer to your vi command summary for help with editing; don't save yet, we need one more edit!

Modify your lattice input to use your new cell 2 by changing the 7s to 2s

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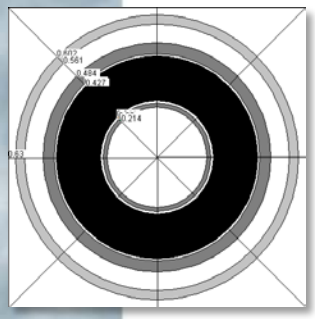
QST#2

Input – Local Materials

To define a local material, a material definition must be provided:



mat	pyrex	2.34	b-10	6.81945E-03
			b-11	3.01805E-02
			o-16	5.35000E-01
			na-23	4.10000E-02
			al-27	1.00000E-02
			si-00	3.77000E-01

user defined material name

density (g/cc)

isotopes, as named in material library

weight fraction

Define materials locally in the insert block

```
[INSERT]
  title "Pyrex"
  npin 17
  mat pyrex      2.34249    b-10    6.81945e-03
                            b-11    6.81945e-03
                            o-16    5.3500e-1
                            na-23   4.1e-2
                            al-27 1e-2
                            si-00 3.77e-1

  cell 1  0.214 0.231 0.241 0.427 0.437 0.484 / he ss he b4c he ss

  rodmap  LAT-PY
     -
     - -
     - - -
     1 - - -
     - - - - -
     - - - - - 1
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  axial PY   0.0 LAT-PY  1.0
```

Change to pyrex

INSERT

- Contains geometry and physical description of burnable poisons (BPs) and/or thimble plugs

Refer to your vi command summary for help with editing; don't forget to save your edited file :x

QST#2
Job Submission/Output

On Leza

Type: *./run-qst-2*

On a local machine like Leza, unless you run the case in the background, the log file will scroll on your screen.

```
000:00.14 Processing XS Libraries...
000:00.83 Generating Materials...
000:00.85 Generating Reactor Geometry...
000:00.85 Generating Reactor Mesh...
000:01.54 Initializing Parallel Environment...
000:01.54 Setting up angular quadrature...
000:01.54 Initializing mesh...
000:01.55 Generating Input Edits...
000:01.74 Initializing Base MOC Sweeper...
              Setting up modular rays...
              Performing ray tracing...
              Setting up long rays...
              Allocating base solution variables...
              Allocating solution variables...
000:02.21 Initializing Multi-group Fixed Source Solver...
              Default convergence norm is being used
              Default step algorithm is being used
              Default solve algorithm is being used
000:02.21 Initializing Eigenvalue Solver...
              Adding eigenvalue accelerator...
               -CMFD acceleration is being used (MG LS, Node-Major)
                   ...with P0 boundary update
                   ...using angle decomp processors
000:02.52 Initializing Feedback Solver...
000:02.52 Initializing MultiState Solver...
000:02.52 Calculating Equivalence XS...
          Solving Subgroup FSP...
          Group  10 Cat  1 92238    16 9.6003E-12
          Group  10 Cat  2 92235    16 3.9510E-12
          Group  10 Cat  3 40091    16 2.8370E-12
                        :
                        :
                        :
          Group  26 Cat  2 92235    16 2.8083E-12
          Group  26 Cat  3 40091    16 1.3180E-12
          Group  26 Cat  4 72177    14 1.7503E-07
000:35.81 Solving State 1/1...
000:51.84 Using TCP0 in All Regions...
000:51.84 Performing Eigenvalue Calculation...
000:51.84       iter     keff      norm_keff     norm_fissrc
000:51.84          0  1.0000000 1.000000E-04 9.990000E-01
          MG-CMFD    4     88    1.1030873   7.252942E-07
          1G-INNER   1          94           7.377167E-01
001:02.28          1  1.1030873 1.030873E-01 6.578645E-03
          MG-CMFD    2     88    1.1053073   2.312306E-04
          1G-INNER   1          94           5.320560E-02
001:11.95          2  1.1053073 2.219933E-03 5.329453E-04
                        :
                        :
                        :
001:31.28          4  1.1073589 2.272270E-04 1.815394E-05
          MG-CMFD    1     88    1.1074028   3.501897E-04
          1G-INNER   1          94           7.465707E-05
001:40.74          5  1.1074028 4.397498E-05 3.132485E-06
001:40.74 Convergence criteria satisfied
001:40.75 Finished
```

Residuals from the self-shielding equivalence XS calculation

Eigenvalue iterations

keff = 1.1074028

VERA processing & output files

- $case.xml – the VERAIn parsed input to the codes
- $case.log – a record of the information echoed to the screen during the run
- $case.out – a human-readable output file
- $case.h5 – a standard hdf5 formatted file containing inputs and outputs
- $case.silo – a file generated from the h5 file that is readable by VisIT or ParaView for visualization

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QST#2 Output

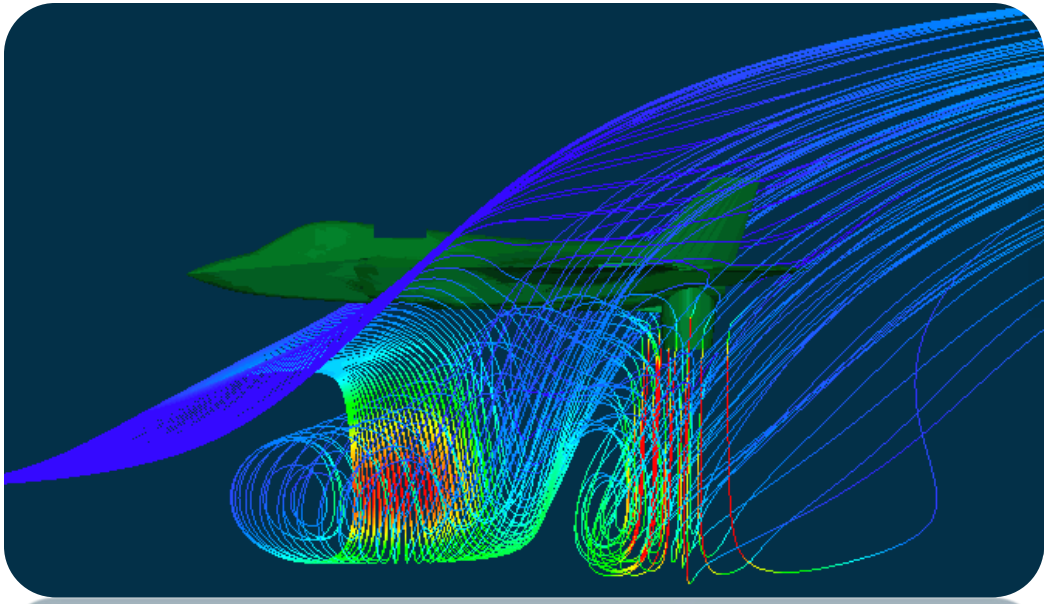
- To view pin powers, type *cat qst-2.out*

```
*******************************************************************************
****************************** STATE_0001 EDITS ******************************
*******************************************************************************

    k-eff = 1.1074028

===============================================================================
                                 3-D Pin Powers
===============================================================================
Assembly   1 at (  1,  1)
y/x       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15      16      17
  1  1.0106  0.9990  0.9958  0.9997  1.0092  1.0294  1.0330  1.0368  1.0383  1.0368  1.0330  1.0294  1.0092  0.9997  0.9958  0.9990  1.0106
  2  0.9990  0.9831  0.9789  0.9785  1.0082  1.0568  1.0419  1.0451  1.0707  1.0451  1.0419  1.0568  1.0082  0.9785  0.9789  0.9831  0.9990
  3  0.9958  0.9789  0.9523  0.9269  1.0100  0.0000  1.0692  1.0712  0.0000  1.0712  1.0692  0.0000  1.0100  0.9269  0.9523  0.9789  0.9958
  4  0.9997  0.9785  0.9269  0.0000  0.9526  1.0363  1.0212  1.0205  1.0266  1.0205  1.0212  1.0363  0.9526  0.0000  0.9269  0.9785  0.9997
  5  1.0092  1.0082  1.0100  0.9526  0.9907  1.0399  1.0034  0.9630  0.9229  0.9630  1.0034  1.0399  0.9907  0.9526  1.0100  1.0082  1.0092
  6  1.0294  1.0568  0.0000  1.0363  1.0399  0.0000  1.0079  0.9123  0.0000  0.9123  1.0079  0.0000  1.0399  1.0363  0.0000  1.0568  1.0294
  7  1.0330  1.0419  1.0692  1.0212  1.0034  1.0079  0.9564  0.9210  0.8813  0.9210  0.9564  1.0079  1.0034  1.0212  1.0692  1.0419  1.0330
  8  1.0368  1.0451  1.0712  1.0205  0.9630  0.9123  0.9210  0.9250  0.9232  0.9250  0.9210  0.9123  0.9630  1.0205  1.0712  1.0451  1.0368
  9  1.0383  1.0707  0.0000  1.0266  0.9229  0.0000  0.8813  0.9232  0.9347  0.9232  0.8813  0.0000  0.9229  1.0266  0.0000  1.0707  1.0383
 10  1.0368  1.0451  1.0712  1.0205  0.9630  0.9123  0.9210  0.9250  0.9232  0.9250  0.9210  0.9123  0.9630  1.0205  1.0712  1.0451  1.0368
 11  1.0330  1.0419  1.0692  1.0212  1.0034  1.0079  0.9564  0.9210  0.8813  0.9210  0.9564  1.0079  1.0034  1.0212  1.0692  1.0419  1.0330
 12  1.0294  1.0568  0.0000  1.0363  1.0399  0.0000  1.0079  0.9123  0.0000  0.9123  1.0079  0.0000  1.0399  1.0363  0.0000  1.0568  1.0294
 13  1.0092  1.0082  1.0100  0.9526  0.9907  1.0399  1.0034  0.9630  0.9229  0.9630  1.0034  1.0399  0.9907  0.9526  1.0100  1.0082  1.0092
 14  0.9997  0.9785  0.9269  0.0000  0.9526  1.0363  1.0212  1.0205  1.0266  1.0205  1.0212  1.0363  0.9526  0.0000  0.9269  0.9785  0.9997
 15  0.9958  0.9789  0.9523  0.9269  1.0100  0.0000  1.0692  1.0712  0.0000  1.0712  1.0692  0.0000  1.0100  0.9269  0.9523  0.9789  0.9958
 16  0.9990  0.9831  0.9789  0.9785  1.0082  1.0568  1.0419  1.0451  1.0707  1.0451  1.0419  1.0568  1.0082  0.9785  0.9789  0.9831  0.9990
 17  1.0106  0.9990  0.9958  0.9997  1.0092  1.0294  1.0330  1.0368  1.0383  1.0368  1.0330  1.0294  1.0092  0.9997  0.9958  0.9990  1.0106

===============================================================================
```

QST#2
ParaView by Kitware

ParaView

- Open-source, multi-platform data analysis and visualization application
- Developed to analyze extremely large datasets using distributed memory computing resources
- Builds visualizations to analyze data using qualitative and quantitative techniques



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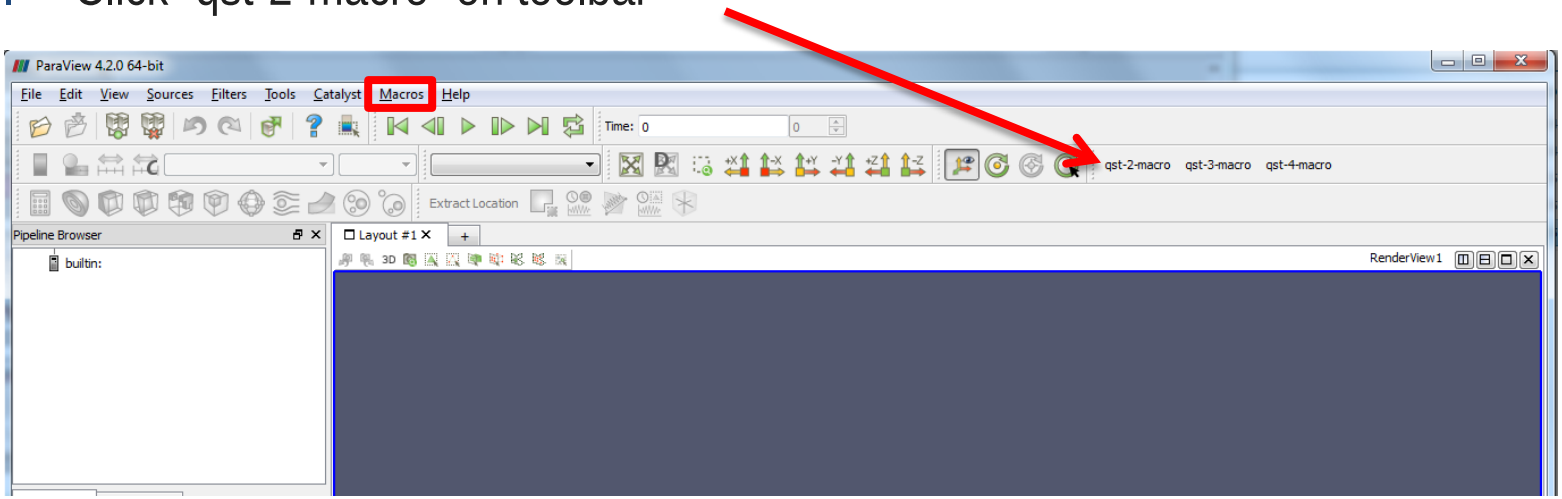
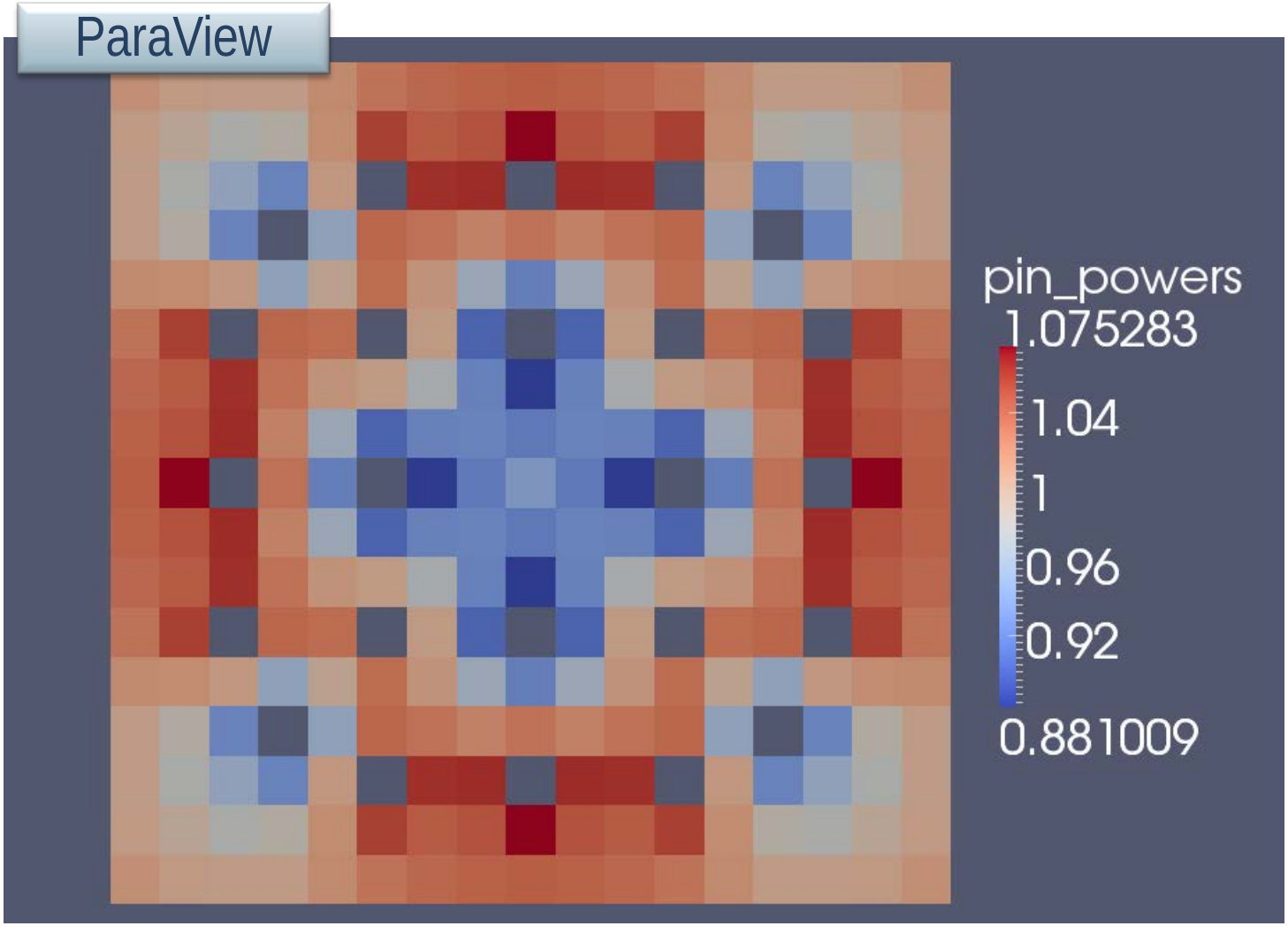
QST#2
Visualizing the Results

ParaView

1. Transfer qst-2.silo file from the server to your machine or your USB drive (see handout)
2. Open ParaView from the USB drive
3. Open the output file, qst-2.silo
4. Click “Macros” from main toolbar
5. Select “Add new macro…” and choose “qst-2-macro.py” (located on the USB drive in the “macros” folder)
6. Click “qst-2-macro” on toolbar



QST#2
Viewing the Results



BREAK

Please log off of Leza

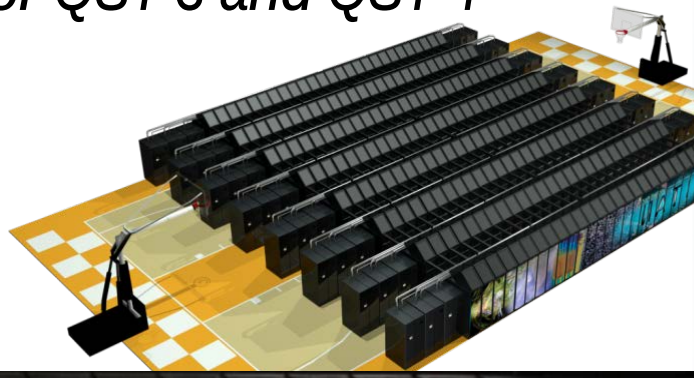
Type "exit" in your access window,

and then disconnect from Leza's wireless access point .....

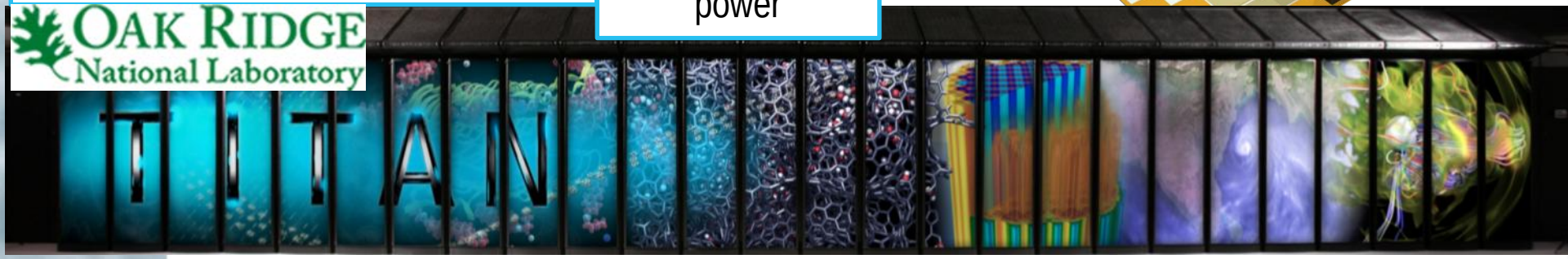
SYSTEM SPECIFICATIONS:

- 18,688 compute nodes, each with:
  - 16-Core 2.2 GHz AMD Opteron 6200 CPU
  - NVIDIA Tesla K20x GPU
- 299,008 cores
- 710 TB total system memory
- $97 Million
- Ranked 3rd in energy efficiency

It's time to log on to Titan!
Connect to the local broadband access
and then
ssh onto Titan for QST-3 and QST-4

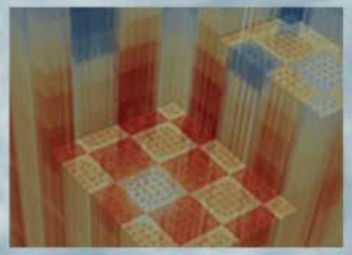


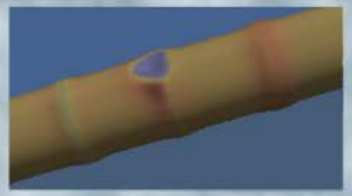
200 cabinets
4,352 ft^2 (404 m^2)
8.2 MW peak power

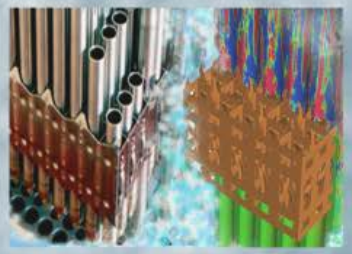


#2 Supercomputer in the World

CASL-U-2015-0067-000







Quick Start Tutorial #3
Neutronics analysis of a 3D hot full power fuel assembly with depletion and thermal-hydraulics feedback

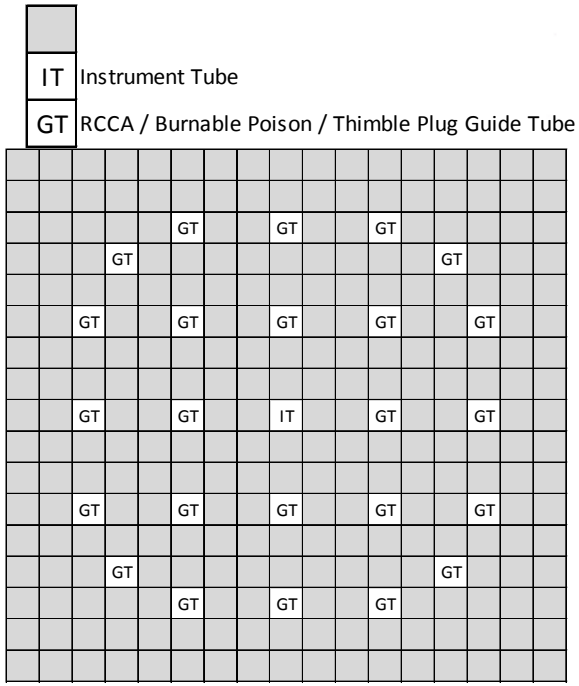
A DOE Energy Innovation Hub

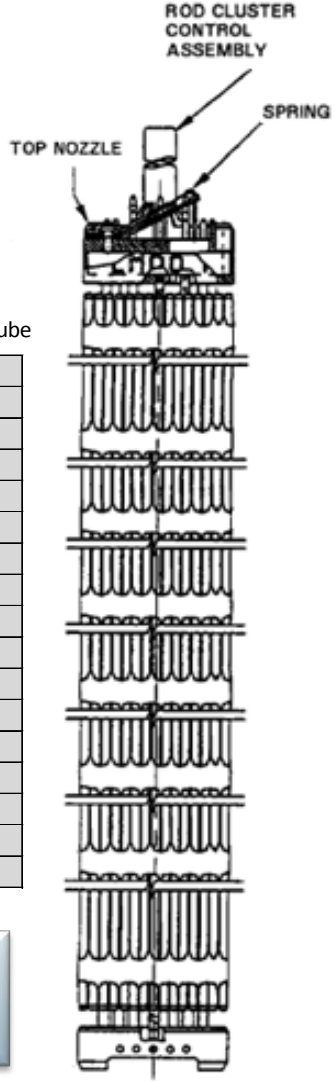
U.S. DEPARTMENT OF ENERGY | NUCLEAR ENERGY

Quick Start Tutorial # 3 – 3D Hot Full Power Assembly

- Neutronics with thermal-hydraulic feedback
- Demonstrates capability to predict:
  - eigenvalue
  - pin power distribution
  - fuel temperatures
  - coolant conditions
- Two depletion steps

Fuel rod and Thimble Arrangement





Exercise objective: set up and run a fuel assembly geometry using symmetric boundary conditions

CASL-U-2015-0067-000

Files you will find in the qst-3 folder

Open the tutorial #3 input deck:
cd *../qst-3*
vi *qst-3.inp*

- qst-3.inp - the input for this case
- run-qst-3 - the script that runs this case
- qst-3-mpact-params – a file that includes the MPACT parameters to run this case
  - we won't be talking about these parameters in this tutorial
- qst-3-cobratf-params – a file that includes the MPACT parameters to run this case

Open qst-3.inp to modify the inputs for the case

CASL-U-2015-0067-000

QST#3 Input

```
[STATE]
  (state parameters)

  feedback off
  deplete hours 0 1 2

[CORE]
  (core parameters)

[ASSEMBLY]
  title "Westinghouse 17x17"
  npin 17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1     0.4096 0.418 0.475 / U31 he zirc4
  cell 2            0.561 0.602 / mod    zirc4      ! guide/instrument tube
  cell 3            0.418 0.475 /      he zirc4      ! plenum
  cell 4                  0.475 /        zirc4      ! end plug
  cell 5                  0.475 /        mod        ! empty

  lattice FUEL
       2
       1 1
       1 1 1
       2 1 1 2
       1 1 1 1 1
       1 1 1 1 1 2
       2 1 1 2 1 1 1
       1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1

  lattice PLEN
       2
       3 3
       3 3 3
       2 3 3 2
       3 3 3 3 3
       3 3 3 3 3 2
       2 3 3 2 3 3 3
       3 3 3 3 3 3 3 3
       3 3 3 3 3 3 3 3 3

  lattice PLUG
       2
       4 4
       4 4 4
       2 4 4 2
       4 4 4 4 4
       4 4 4 4 4 2
       2 4 4 2 4 4 4
       4 4 4 4 4 4 4 4
       4 4 4 4 4 4 4 4 4
```

STATE

- [STATE] block describes reactor core operating parameters (statepoint values) at a particular point in time. Can change during run.

ASSEMBLY

- [ASSEMBLY] block contains the geometry and physical description of the nuclear fuel assemblies.

QST#3 Input

EDITS

- Specifies axial levels at which power and/or neutronics-T/H coupling will be solved

```
  axial ASSY   6.053
        GAP   10.281
        PLUG  11.951
        FUEL  377.711
        PLEN  393.711
        PLUG  395.381
        GAP   397.51

  grid END inc   1017 3.866
  grid MID zirc4 875  3.810

  grid_axial
      END  13.884
      MID  75.2
      MID 127.4
      MID 179.6
      MID 231.8
      MID 284.0
      MID 336.2
      END 388.2

  lower_nozzle  ss 6.053 6250.0  ! mat, height, mass (g)
  upper_nozzle  ss 8.827 6250.0  ! mat, height, mass (g)

[EDITS]

axial_edit_bounds
      11.951
      15.817
      44.556
      73.295
      77.105
      101.3
      125.495
      129.305
      153.5
      177.695
      181.505
      205.7
      229.895
      233.705
      257.9
      282.095
      285.905
      310.1
      334.295
      338.105
      361.8686
      377.711

[MPACT]
  include qst-3-mpact-params

[COBRATF]
  include qst-3-cobratf-params
```

QST#3
Input – [STATE]

feedback	on	flag for T/H feedback (on or off)
deplete	hours 0 1 2	Depletion units (“EFPD”, “GWDMT”, “hours”) and list of exposure steps

```
[STATE]
  title 'State 1'
  power     100.0
  flow      100.0
  tinlet    565.0 K
  pressure 2250            ! psia
  boron     1300           ! ppmB

  sym       qtr
  xenon     equil

  tfuel     600 K
  modden    0.743          ! g/cc

  feedback off
  deplete hours 0 1 2
```

We will run using thermal-hydraulic feedback, so edit your input so that it is “on”

For this case, we would like to deplete at 0, 1 and 2 EFPD; edit the input appropriately

All caps required!

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QST#3
Input – [ASSEMBLY]

cell	1	0.4096	0.418	0.475	/	U31	he	zirc4	→ fuel
cell	2		0.561	0.602	/		mod	zirc4	→ guide/instrument tube
cell	3		0.418	0.475	/		he	zirc4	→ plenum
cell	4			0.475	/			zirc4	→ end plug
cell	5			0.475	/			mod	→ empty

radii

materials

To define the lattice, each unique cell is defined. Inserts are defined using this same format. Control rods are defined the same way, but within their own [CONTROL] block

```
[ASSEMBLY]
  title "Westinghouse 17x17"
  npin 17
  ppitch 1.26

  fuel U31 10.257 94.5 / 3.1

  cell 1      0.4096 0.418 0.475 / U31 he zirc4
  cell 2             0.561 0.602 / mod    zirc4
  cell 3             0.418 0.475 /     he zirc4
  cell 4                   0.475 /        zirc4
  cell 5                   0.475 /        mod

  lattice FUEL
       2
       1 1
       1 1 1
       2 1 1 2
       1 1 1 1 1
       1 1 1 1 1 2
       2 1 1 2 1 1 1
```

QST#3
Input – [ASSEMBLY]

Using the cells defined previously, each unique lattice pattern must be defined For this example, 1/8th symmetry is used

```
lattice FUEL
     2
     1 1
     1 1 1
     2 1 1 2
     1 1 1 1 1
     1 1 1 1 1 2
     2 1 1 2 1 1 1
     1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
```

cell 2 guide tube

cell 1 fuel

```
lattice PLEN
     2
     3 3
     3 3 3
     2 3 3 2
     3 3 3 3 3
     3 3 3 3 3 2
     2 3 3 2 3 3 3
     3 3 3 3 3 3 3 3
     3 3 3 3 3 3 3 3 3
```

Five cell types used:

cell	1	fuel
cell	2	guide tube
cell	3	plenum
cell	4	end plug
cell	5	moderator

```
lattice PLUG
     2
     4 4
     4 4 4
     2 4 4 2
     4 4 4 4 4
     4 4 4 4 4 2
     2 4 4 2 4 4 4
     4 4 4 4 4 4 4 4
     4 4 4 4 4 4 4 4 4
```

```
lattice GAP
     2
     5 5
     5 5 5
     2 5 5 2
     5 5 5 5 5
     5 5 5 5 5 2
     2 5 5 2 5 5 5
     5 5 5 5 5 5 5 5
     5 5 5 5 5 5 5 5 5
```

Remember that the lattice pattern likely changes in the axial direction!

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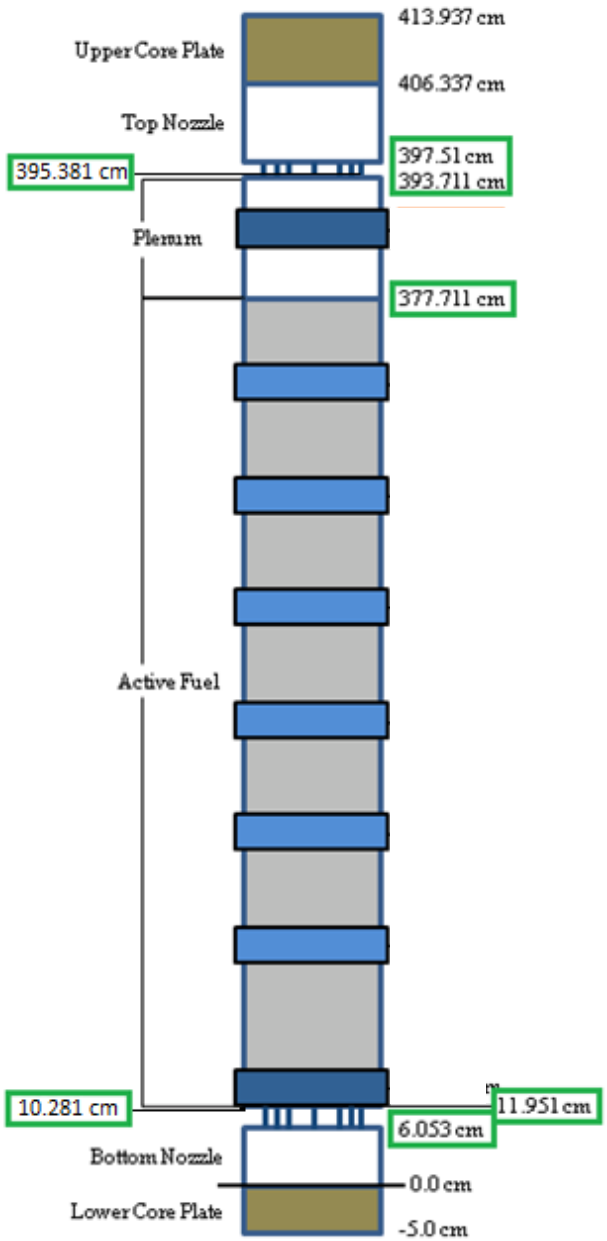
QST#3 Input – [ASSEMBLY]



The fuel assembly is built axially by stacking up lattice definitions.

assembly label

axial	ASSY	6.053
	GAP	10.281
	PLUG	11.951
	FUEL	320
	PLEN	393.711
	PLUG	395.381
	GAP	397.51

All axial elevations are relative to the top of the bottom core plate (the fuel assembly seating surface).

The top of our fuel stack is at 377.711 cm; modify the input appropriately.

```
lattice GAP
     2
     5 5
     5 5 5
     2 5 5 2
     5 5 5 5 5
     5 5 5 5 5 2
     2 5 5 2 5 5 5
     5 5 5 5 5 5 5 5
     5 5 5 5 5 5 5 5 5

axial ASSY   6.053
      GAP   10.281
      PLUG  11.951
      FUEL  320
      PLEN  393.711
      PLUG  395.381
      GAP   397.51

grid END inc   1017 3.866
grid MID zirc4 875  6.5

grid_axial
    END  13.884
    MID  75.2
    MID 127.4
```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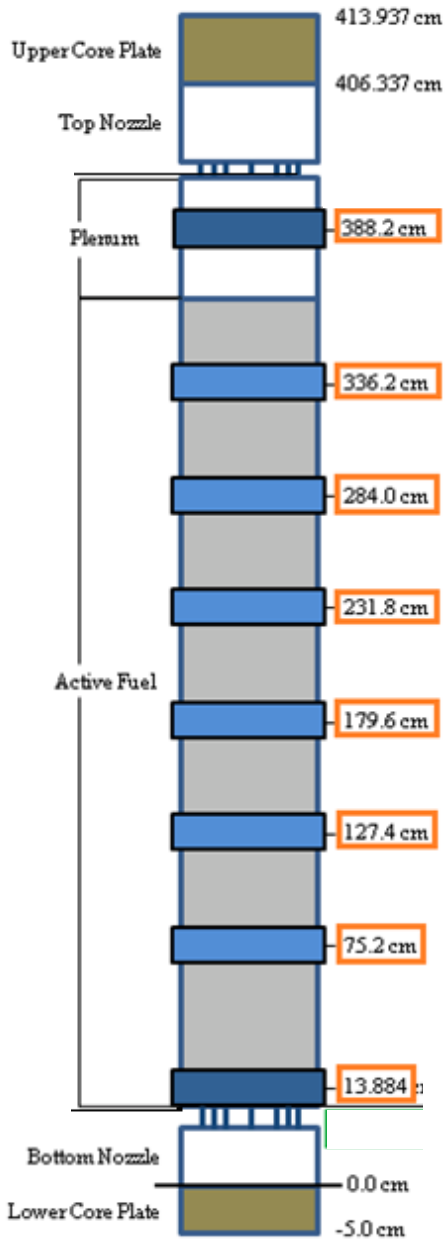
QST#3 Input – [ASSEMBLY]



grid	END	inc	1017	3.866	grid label, material, mass (g), height (cm)
grid	MID	zirc4	875	3.810	grid label, material, mass (g), height (cm)

grid_axial	END	13.884
	MID	75.2
	MID	127.4
	MID	179.6
	MID	231.8
	MID	284.0
	MID	336.2
	END	388.2

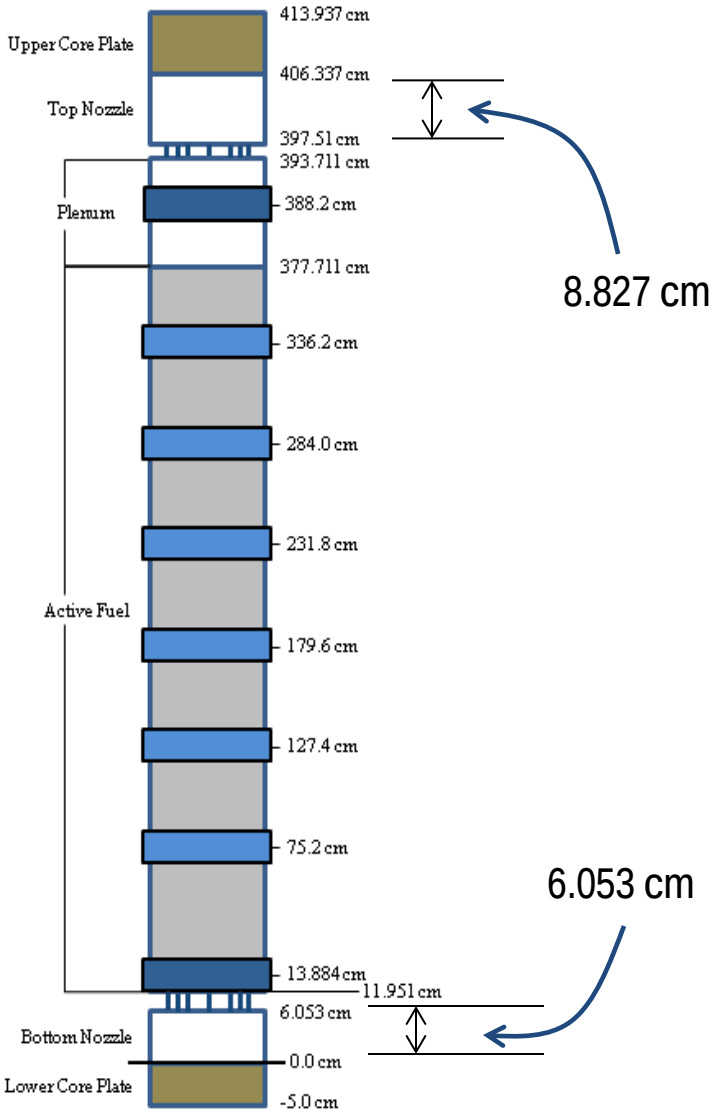
Grid elevations are from bottom of bottom nozzle to the axial centerline of the grid. The bottom of the bottom nozzle (or the top of the lower core plate is always defined as zero in VERA.

```
     5 5 5 5 5 5 5 5
     5 5 5 5 5 5 5 5 5

axial ASSY   6.053
      GAP   10.281
      PLUG  11.951
      FUEL  320
      PLEN  393.711
      PLUG  395.381
      GAP   397.51

grid END inc   1017 3.866
grid MID zirc4 875  6.5

grid_axial
    END  13.884
    MID  75.2
    MID 127.4
    MID 179.6
    MID 231.8
    MID 284.0
    MID 336.2
    END 388.2

lower_nozzle  ss 6.053 6250.0
upper_nozzle  ss 8.827 6250.0
```

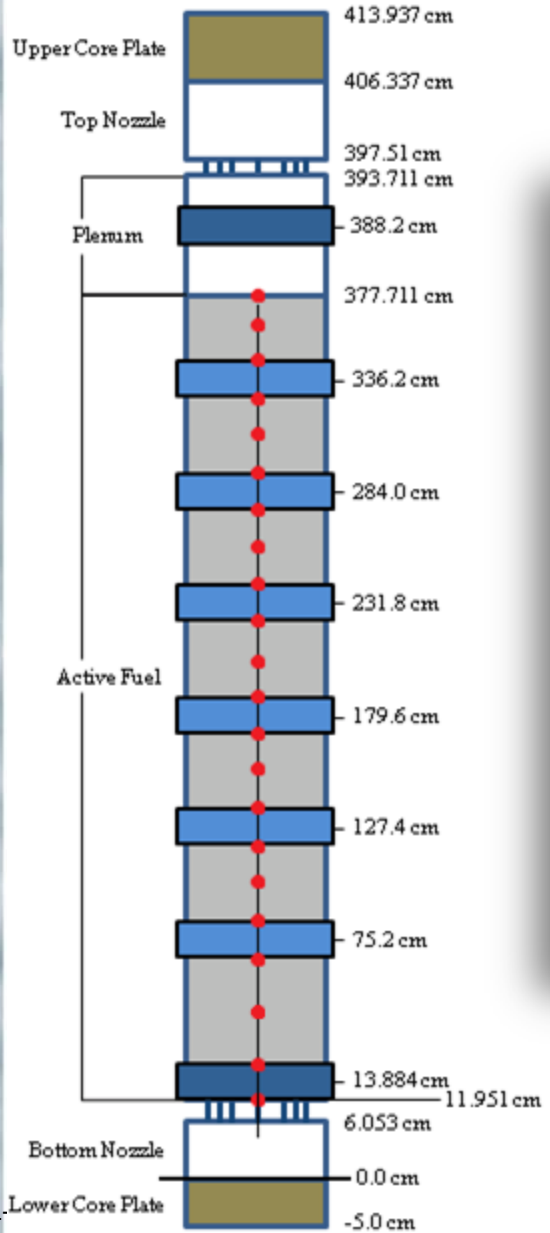
For our problem the mid-grid is 3.810cm tall. Modify the input appropriately.

QST#3 Input – [ASSEMBLY]

lower_nozzle	ss 6.053 6250.0	lower nozzle material, height (cm), mass (g)
upper_nozzle	ss 8.827 6250.0	upper nozzle material, height (cm), mass (g)



QST#3
Input – [EDITS]




```
      END 388.2

  lower_nozzle  ss 6.053 6250.0
  upper_nozzle  ss 8.827 6250.0

[EDITS]

axial_edit_bounds
      11.951
      15.817
      44.556
      73.295
      77.105
      101.3
      125.495
      129.305
      153.5
      177.695
      181.505
      205.7
      229.895
      233.705
      257.9
      282.095
      285.905
      310.1
      334.295
      338.105
      361.8686
      377.711
```

- The axial edits define both the visualization data points written, but also controls the mesh used in solving
- Thus, the number of axial locations directly influences how many processors are used
- These are the user-specified mesh locations. The code adds others automatically above and below the active fuel.
- Using this small number of axial locations is not recommended. CASL uses a 3” axial mesh for most applications

QST#3
Run Scripting

parse input

```
perl   $parser.pl   --init   $case.inp   $case.xml
```

run T/H Preprocessor

```
aprun   -n   1    $COBPRE.exe   --xmlfile=$case.xml
```

run Neutronics-T/H

```
aprun   -n   $cores   $MPACT.exe   $case.xml
```

Note the addition of the subchannel component since we are using the coupled thermal-hydraulics option

QST#3
Job Submission/Output

For Titan

Type: *qsub run-qst-3*

Titan will reply with a number. This is your job number.

To see where your job is in the queue,

type *qstat*

Once it is running, view your output on Titan as it is computed:

type *tail –f {job #}*

```
==========================================
   Running Job on 16 cores
==========================================


==============================================================================
                                MPACT v1.0.0      (  rev: 4063   SHA1: 3c98577)
                                                  (built: 13:19:18 Nov 26 2014)
          Executing case: qst3
          by tet on natasha.ornl.gov at 13:16:21, Mar. 05, 2015...

==============================================================================
  000:00.02 Processing Input...
  000:00.73 Processing XS Libraries...
  000:02.18 Generating Materials...
  000:02.23 Generating Reactor Geometry...
  000:02.24 Generating Reactor Mesh...
  000:03.03 Initializing Parallel Environment...
  000:03.05 Setting up angular quadrature...
  000:03.05 Initializing mesh...
  000:03.12 Generating Input Edits...
                Setting up modular rays...
                Performing ray tracing...
  000:04.10 Initializing Base MOC Sweeper...
                Setting up long rays...
  000:04.11 Initializing PS 2D1D Sweeper...
                      ...with LFLAT axial TL spatial treatment
                      ...with ISO axial TL angular treatment
                      ...with axial TL splitting
  000:04.17 Initializing Nodal Sweeper...
                 -One-Node SP3 is being used
                      ...with radial TL splitting
  000:04.18 Initializing Multi-group Fixed Source Solver...
  000:04.19 Initializing Eigenvalue Solver...
                Adding eigenvalue accelerator...
                 -CMFD acceleration is being used (MG LS, Node-Major)
                      ...with PO boundary update
                      ...not using angle decomp processors
  000:04.58 Initializing COBRA-TF Interface...

Reading CARD GROUP     1

Reading CARD GROUP     2

Reading CARD GROUP     3

Reading CARD GROUP     4

Reading CARD GROUP     7

Reading CARD GROUP     8

Reading CARD GROUP     9

Reading CARD GROUP    10

Reading CARD GROUP    11

Reading CARD GROUP    12

Reading CARD GROUP    13

Reading CARD GROUP   -14

Reading CARD GROUP    15

Reading CARD GROUP    17

Reading CARD GROUP    18

  Subroutine setin finished.

 Cross check of the input values finished.
```

QST#3 Output

```
  002:18.01 solving state 2/3...
  002:18.01 performing depletion...
  002:18.01 burnup =    0.0384 MWD/kgHM    1.00 EFPD
  002:18.01 predictor step...
  002:19.83 computing equilibrium xenon concentration...
  002:24.11 calling COBRA-TF...
 Rank           0  Step           1 Energy storage =    2818.3833723504849
 Rank           0  Step         100 Energy storage =    1.2102292832131907
 Rank           0  Step         200 Energy storage =   0.44522918189612909
Convergence reached, ending pseudo transient
Number of steps =   214
         Quantity  Value (%)  Criteria (%)
 Global energy balance =      0.0057        0.0100
   Global mass balance =      0.0099        0.0100
  Fluid energy storage =      0.0422        0.5000
          Mass storage =      0.0638        0.5000
  Solid energy storage =      0.3112        0.5000

Averaging CTF output distributions
  Max pin-average cool temperature =  327.535 [C] at rod n=    11  level= 21
  Min pin-average cool temperature =  292.021 [C] at rod n=    51  level=  1
  Max pin-average clad temperature =  352.937 [C] at rod n=    30  level= 15
  Min pin-average clad temperature =  292.021 [C] at rod n=    51  level=  1
  Max pin-average fuel temperature =  813.993 [C] at rod n=    50  level= 11
  Min pin-average fuel temperature =  292.021 [C] at rod n=    51  level=  1
Linear heat rate given in CTF input file [W/cm]          = 182.9938
Linear heat rate obtained from neutronics coupling [W/cm] = 182.9938
Power to model [W] =  4417500.00
Active length of model [cm] =      365.76
Number fuel rods =     72.2500
Number guide tubes =      6.2500
                  Outlet temperature was 599.975 K...
                  Maximum centerline fuel temperature was 1410.055 K...
                  Maximum temperature change was 2.404366E+01 K...
                  Maximum moderator density change was 1.330562E-03 g/cc...
  002:46.44 using TCPO in All Regions...
  002:46.44          2  1.2071113 1.385947E-02 7.597129E-02
            MG-CMFD    2   218    1.2094871   1.231355E+00
            NODAL      5          5           7.746776E-03
            1G-INNER   1         94           3.379149E-03
  003:03.28          3  1.2094871 2.375779E-03 4.632840E-02
  003:03.30 convergence criteria satisfied
  003:03.30 corrector step...
  003:03.30 computing equilibrium xenon concentration...
  003:08.12 calling COBRA-TF...
 Rank           0  Step           1 Energy storage =    4830.3167444850560
 Rank           0  Step         100 Energy storage =    3.5521742623309507
 Rank           0  Step         200 Energy storage =    1.1244504335779998
 Rank           0  Step         300 Energy storage =   0.40811050795435250
Convergence reached, ending pseudo transient
Number of steps =   400
         Quantity  Value (%)  Criteria (%)
 Global energy balance =      0.0002        0.0100
   Global mass balance =      0.0098        0.0100
  Fluid energy storage =      0.0027        0.5000
          Mass storage =      0.0098        0.5000
  Solid energy storage =      0.0427        0.5000
 Rank           0  Step         400 Energy storage =    4.5397930631618566E-002

Averaging CTF output distributions
  Max pin-average cool temperature =  327.738 [C] at rod n=    11  level= 21
  Min pin-average cool temperature =  291.921 [C] at rod n=    81  level=  1
  Max pin-average clad temperature =  356.872 [C] at rod n=    30  level= 14
  Min pin-average clad temperature =  291.922 [C] at rod n=     7  level=  1
  Max pin-average fuel temperature =  877.860 [C] at rod n=    50  level= 11
  Min pin-average fuel temperature =  291.922 [C] at rod n=     7  level=  1
Linear heat rate given in CTF input file [W/cm]          = 182.9938
Linear heat rate obtained from neutronics coupling [W/cm] = 182.9938
Power to model [W] =  4417500.00
Active length of model [cm] =      365.76
Number fuel rods =     72.2500
Number guide tubes =      6.2500
                  Outlet temperature was 599.991 K...
                  Maximum centerline fuel temperature was 1525.159 K...
                  Maximum temperature change was 8.767413E+01 K...
                  Maximum moderator density change was 2.851289E-03 g/cc...
  003:47.24 using TCPO in All Regions...
  003:47.24          3  1.2094871 2.375779E-03 4.632840E-02
            MG-CMFD    2   218    1.2097369   6.624850E-01
            NODAL      5          5           4.969223E-03
            1G-INNER   1         94           2.416480E-03
  004:04.07          4  1.2097369 2.498621E-04 4.335403E-02
  004:04.07 convergence criteria satisfied
  004:04.07 burnup =    0.0384 MWD/kgHM    1.00 EFPD  keff = 1.209737
Enthalpy, in kJ/kg, was:  1299.1370 now:  1299.1370
  Pressure, in MPa, was:    15.5132 now:    15.5132
    Flow, in kg/s,  was:    21.4921 now:    21.4921
  004:04.19 solving state 3/3...
  004:04.19 performing depletion...
```

State 2

Starting State 3

T-H

Neutronics

T-H

Neutronics

QST#3 Output

```
Linear heat rate given in CTF Input file [W/cm]          = 182.9938
Linear heat rate obtained from neutronics coupling [W/cm] = 182.9938
Power to model [W] =  4417500.00
Active length of model [cm] =      365.76
Number fuel rods =     72.2500
Number guide tubes =      6.2500
                  Outlet temperature was 599.989 K...
                  Maximum centerline fuel temperature was 1516.983 K...
                  Maximum temperature change was 1.141441E+01 K...
                  Maximum moderator density change was 7.811254E-05 g/cc...
  004:18.25 Using TCPO in All Regions...
  004:18.25         4  1.2097369 2.498621E-04 4.335403E-02
            MG-CMFD    2   218    1.2086668   7.639570E-01
            NODAL      5          5           4.928967E-03
            1G-INNER   1         94           2.492891E-03
  004:37.12         5  1.2086668 1.070147E-03 3.848977E-02
  004:37.12 Convergence criteria satisfied
  004:37.12 Corrector Step...
  004:37.12 Computing Equilibrium Xenon Concentration...
  004:42.85 Calling Cobra-TF...
 Rank            0  Step            1 Energy Storage =    821.01010070875918
 Rank            0  Step          100 Energy Storage =   0.36941243585378830
Convergence Reached, Ending Pseudo Transient
Number of Steps =   174
          Quantity  Value (%)  Criteria (%)
 Global Energy Balance =      0.0008        0.0100
   Global Mass Balance =      0.0096        0.0100
  Fluid Energy Storage =      0.0077        0.5000
          Mass Storage =      0.0182        0.5000
  Solid Energy Storage =      0.0841        0.5000

Averaging CTF output distributions
  max pin-average cool temperature =  327.730 [C] at rod n=    11  level= 21
  min pin-average cool temperature =  291.913 [C] at rod n=    81  level=  1
  max pin-average clad temperature =  356.577 [C] at rod n=    30  level= 14
  min pin-average clad temperature =  291.914 [C] at rod n=     7  level=  1
  max pin-average fuel temperature =  863.253 [C] at rod n=    50  level= 11
  min pin-average fuel temperature =  291.914 [C] at rod n=     7  level=  1
Linear heat rate given in CTF Input file [W/cm]          = 182.9938
Linear heat rate obtained from neutronics coupling [W/cm] = 182.9938
Power to model [W] =  4417500.00
Active length of model [cm] =      365.76
Number fuel rods =     72.2500
Number guide tubes =      6.2500
                  Outlet temperature was 599.989 K...
                  Maximum centerline fuel temperature was 1498.792 K...
                  Maximum temperature change was 1.673892E+01 K...
                  Maximum moderator density change was 5.686108E-04 g/cc...
  005:02.85 Using TCPO in All Regions...
  005:02.85         5  1.2086668 1.070147E-03 3.848977E-02
            MG-CMFD    2   218    1.2086447   5.471743E-01
            NODAL      5          5           4.076575E-03
            1G-INNER   1         94           1.807508E-03
  005:21.35         6  1.2086447 2.212243E-05 3.624019E-02
  005:21.35 Convergence criteria satisfied
  005:21.35 Burnup =   0.0768 MWD/kgHM    2.00 EFPD  keff = 1.208645
  005:21.36 Finished
```

keff

VERA processing & output files

- $case.xml – the VERAIn parsed input to the codes
- $case.log – a record of the information echoed to the screen during the run
- $case.out – a human-readable output file
- $case.h5 – a standard hdf5 formatted file containing inputs and outputs
- $case.silo – files generated from the h5 file that is readable by VisIT or ParaView for visualization. For qst-3 you will have three silo files, one for each depletion step.

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QST#3 Output

```
==============================================================================
                    Axially-Integrated 2-D Assembly Powers
==============================================================================
y/x      1
  1  1.0000
==============================================================================
                    Axially-Integrated 2-D Pin Powers
==============================================================================
Assembly   1 at (  1,  1)
y/x      1      2      3      4      5      6      7      8      9
  1  0.0000  1.0311  1.0301  0.0000  1.0264  1.0267  0.0000  1.0083  0.9783
  2  1.0311  1.0126  1.0117  1.0325  1.0082  1.0069  1.0236  0.9945  0.9779
  3  1.0301  1.0117  1.0132  1.0392  1.0144  1.0077  1.0222  0.9885  0.9739
  4  0.0000  1.0325  1.0392  0.0000  1.0407  1.0406  0.0000  1.0115  0.9728
  5  1.0264  1.0082  1.0144  1.0407  1.0258  1.0490  1.0283  0.9851  0.9689
  6  1.0267  1.0069  1.0077  1.0406  1.0490  0.0000  1.0140  0.9690  0.9568
  7  0.0000  1.0236  1.0222  0.0000  1.0283  1.0140  0.9807  0.9517  0.9513
  8  1.0083  0.9946  0.9885  1.0115  0.9851  0.9690  0.9517  0.9404  0.9457
  9  0.9783  0.9779  0.9739  0.9728  0.9689  0.9568  0.9513  0.9457  0.9536
==============================================================================
                         1-D Core Powers
==============================================================================
 iz     Midpint      Min z      Max z    Power
  1      2.5000     0.0000     5.0000    0.0000
  2      8.0265     5.0000    11.0530    0.0000
  3     14.0020    11.0530    16.9510    0.0000
  4     18.8840    16.9510    20.8170    0.1759
  5     35.1865    20.8170    49.5560    0.3900
  6     63.9255    49.5560    78.2950    0.7023
  7     80.2000    78.2950    82.1050    0.8225
  8     94.2025    82.1050   106.3000    1.0020
  9    118.3975   106.3000   130.4950    1.1559
 10    132.4000   130.4950   134.3050    1.1591
 11    146.4025   134.3050   158.5000    1.2859
 12    170.5975   158.5000   182.6950    1.3545
 13    184.6000   182.6950   186.5050    1.3030
 14    198.6025   186.5050   210.7000    1.3919
 15    222.7975   210.7000   234.8950    1.3851
 16    236.8000   234.8950   238.7050    1.2889
 17    250.8025   238.7050   262.9000    1.3289
 18    274.9975   262.9000   287.0950    1.2384
 19    289.0000   287.0950   290.9050    1.0989
 20    303.0025   290.9050   315.1000    1.0679
 21    327.1975   315.1000   339.2950    0.8647
 22    341.2000   339.2950   343.1050    0.6759
 23    354.9868   343.1050   366.8686    0.5427
 24    374.7898   366.8686   382.7110    0.2806
 25    386.9890   382.7110   391.2670    0.0000
 26    393.2000   391.2670   395.1330    0.0000
 27    396.9220   395.1330   398.7110    0.0000
 28    400.6105   398.7110   402.5100    0.0000
 29    406.9235   402.5100   411.3370    0.0000
 30    415.1370   411.3370   418.9370    0.0000
```

- To view pin powers, vi qst-2.out file
- In vi, search for “Axially” by typing /Axially
- Exit vi by hitting the escape key, then typing :q!

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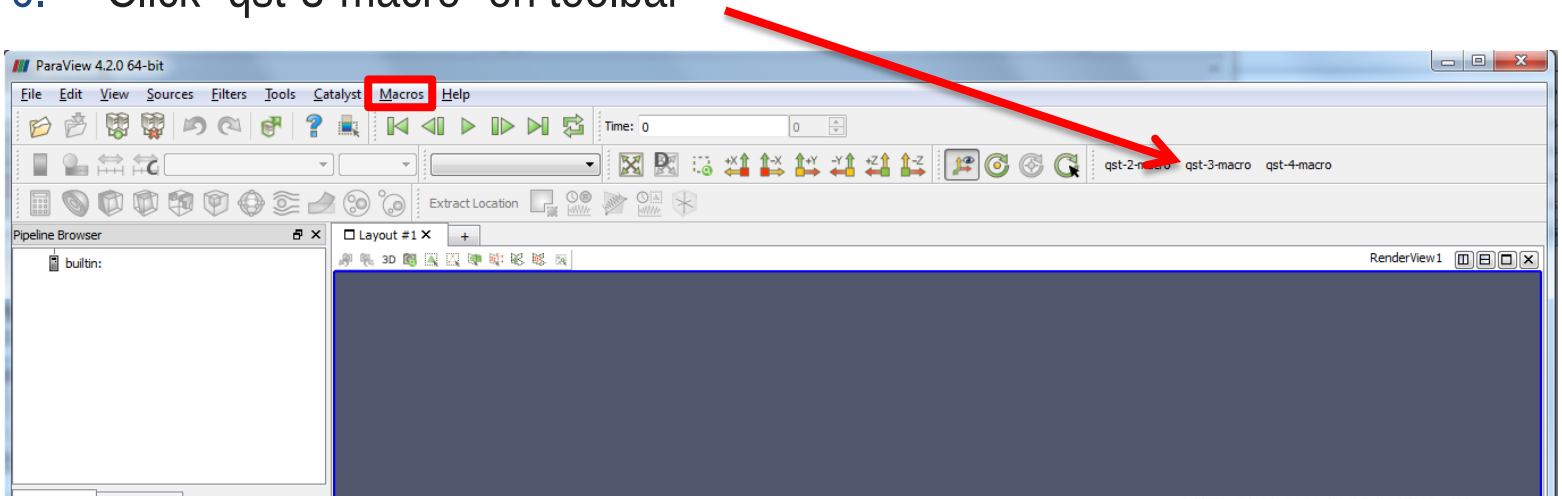
QST#3
Visualizing the Results

ParaView

1. Transfer qst-3_0001.silo file from Titan to your machine or your USB drive (see handout)
2. Open ParaView from the USB drive
3. Open the output file, qst-3_0001.silo
4. Click “Macros” from main toolbar
5. Select “Add new macro…” and choose “qst-3-macro.py” (located on the USB drive in the “macros” folder)
6. Click “qst-3-macro” on toolbar



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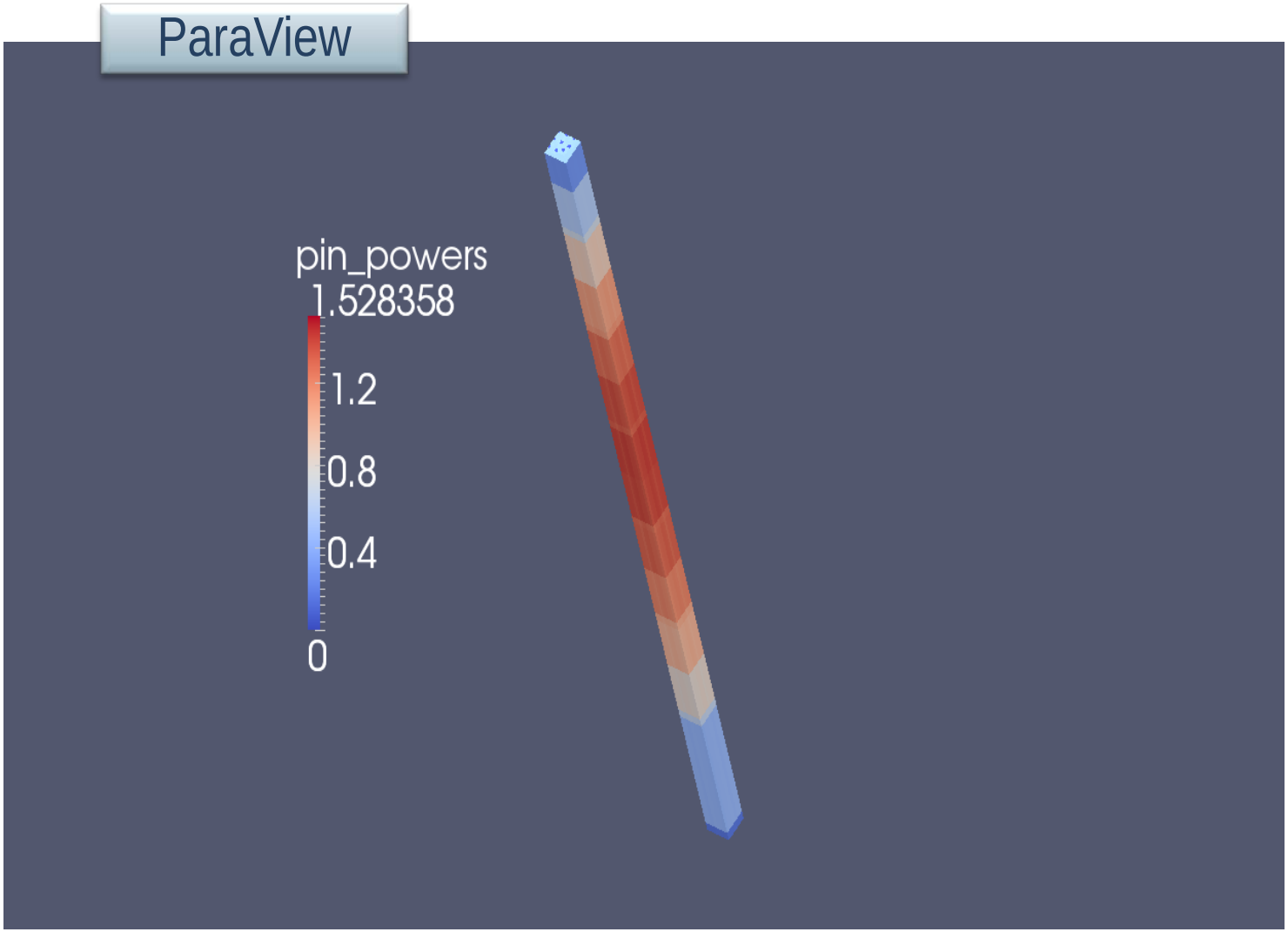
QST#3 Visualization



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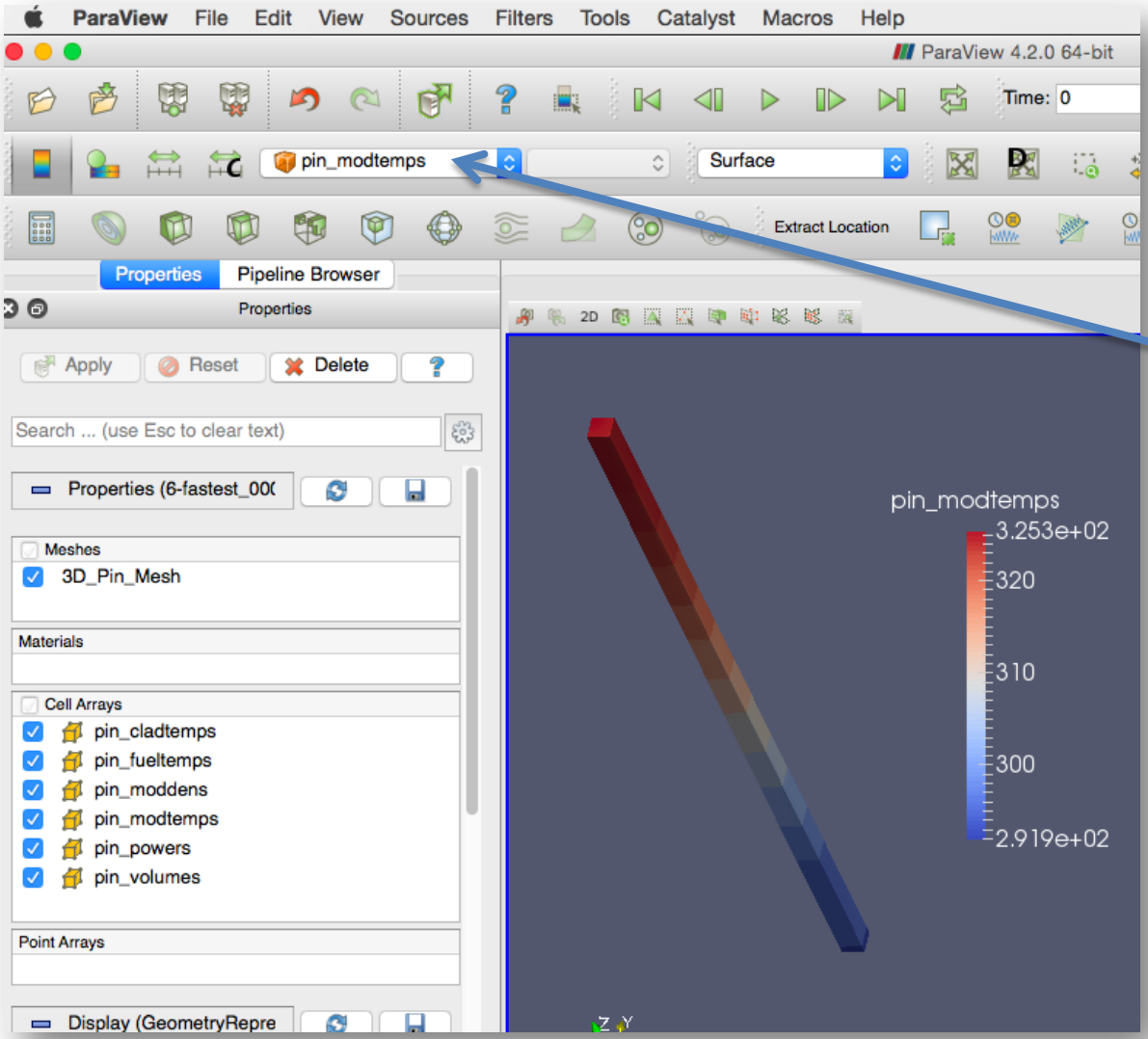
QST#3 Visualization



Click here to see results for other parameters

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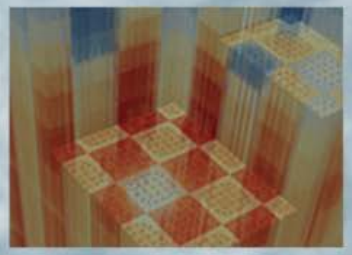
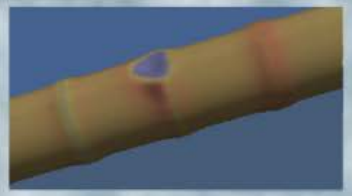
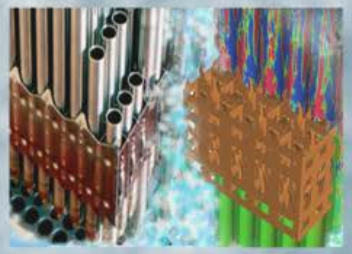




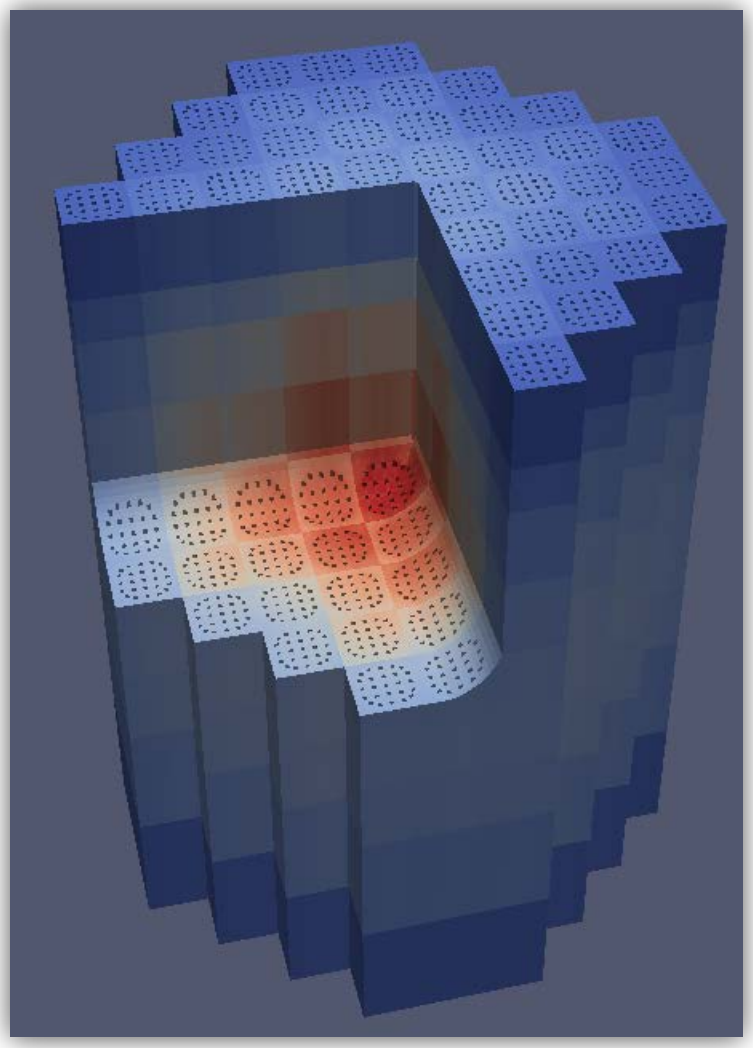


Quick Start Tutorial #4
3D small reactor core thermal-hydraulic feedback

U.S. DEPARTMENT OF ENERGY | NUCLEAR ENERGY

Quick Start Tutorial # 4
Small Reactor Core

- 3D core with quarter core symmetry
- 57 assemblies (total)
- 1 GW_{th}
- Three different fuel enrichments
- BOL HFP isothermal conditions



Files you will find in the qst-4 folder

Open the tutorial #4 input deck:
cd *qst-4*
vi *qst-4.inp*

- qst-4.inp - the input for this case
- run-qst-4 - the script that runs this case
- qst-4-mpact-params – a file that includes the MPACT parameters to run this case
  - we won't be talking about these parameters in this tutorial

Open qst-4.inp to modify the inputs for the case

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QST#4 Input

```
[STATE]
  title 'Case 1'
  power    100.0
  tinlet   565.0 K
  pressure 2250          ! psia
  boron    1300          ! ppmB

  sym      qtr
  feedback off
  xenon    equil

  tfuel    600 K
  modden   0.743         ! g/cc

[CORE]
  size   9               ! assemblies across core
  apitch 21.5
  rated  1007.19 38.9    ! MW, Mlbs/hr
  height 306.337

  core_shape
     0 0 0 1 1 1 0 0 0
     0 0 1 1 1 1 1 0 0
     0 1 1 1 1 1 1 1 0
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     0 1 1 1 1 1 1 1 0
     0 0 1 1 1 1 1 0 0
     0 0 0 1 1 1 0 0 0

  assm_map

    1
    2 1
    1 2 3
    2 1 3
    3 3

  lower_plate ss  5.0 0.5   ! mat, thickness, vol frac
  upper_plate ss  7.6 0.5

  bc_rad vacuum

[ASSEMBLY]
  title "Westinghouse 17x17"
  npin 17
  ppitch 1.260

  fuel U21 10.257 94.5 / 2.110
  fuel U26 10.257 94.5 / 2.619
  fuel U31 10.257 94.5 / 3.100

  cell 1     0.4096 0.418 0.475 / U21 he zirc4
  cell 2     0.4096 0.418 0.475 / U26 he zirc4
  cell 3     0.4096 0.418 0.475 / U31 he zirc4
  cell 4            0.561 0.602 / mod    zirc4      ! guide/instrument tube
  cell 5            0.418 0.475 /     he zirc4      ! plenum
  cell 6                  0.475 /        zirc4      ! plug
  cell 7                  0.475 /        mod        ! empty

  lattice LAT21
       4
       1 1
       1 1 1
       4 1 1 4
       1 1 1 1 1
       1 1 1 1 1 4
       4 1 1 4 1 1 1
       1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1
```

CORE

- [CORE] Describes core size and layout of assemblies, rods, inserts, and detectors

QST#4
Input – [CORE]

size	9	# of assemblies across the flats
apitch	23	assembly pitch
rated	1007 38.9	rated power and flow; MWth and Mlbs/hr
height	306.337	total axial distance from bottom core plate to upper core plate

```
[CORE]
  size   9                  ! assemblies across core
  apitch 23
  rated  1007.19 38.9       ! MW, Mlbs/hr
  height 306.337

  core_shape
     0 0 0 1 1 1 0 0 0
     0 0 1 1 1 1 1 0 0
     0 1 1 1 1 1 1 1 0
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     0 1 1 1 1 1 1 1 0
     0 0 1 1 1 1 1 0 0
     0 0 0 1 1 1 0 0 0

  assm_map

    3
    2 3
    3 2 1
    2 3 1
    1 1

  lower_plate ss  5.0 0.5   ! mat, thickness, vol frac
  upper_plate ss  7.6 0.5
```

For this problem, we'd like to analyze an assembly pitch of 21.5cm. Change the input appropriately.

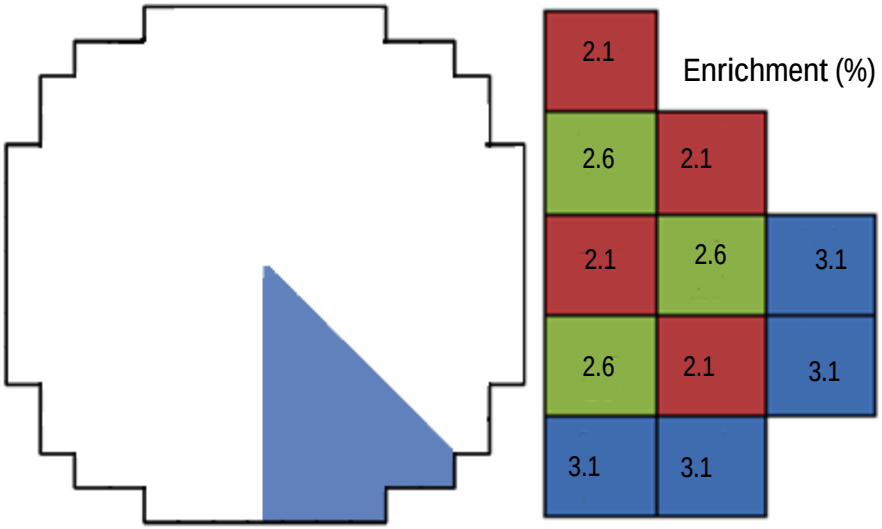
QST#4
Input – [CORE]

core_shape	0 0 0 1 1 1 0 0 0 0 0 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 0 0 0 0 0 1 1 1 0 0 0	map of either 0's or 1's indicating assembly locations

```
[CORE]
  size   9                  ! assemblies across core
  apitch 23
  rated  1007.19 38.9       ! MW, Mlbs/hr
  height 306.337

  core_shape
     0 0 0 1 1 1 0 0 0
     0 0 1 1 1 1 1 0 0
     0 1 1 1 1 1 1 1 0
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     0 1 1 1 1 1 1 1 0
     0 0 1 1 1 1 1 0 0
     0 0 0 1 1 1 0 0 0

  assm_map

    3
    2 3
    3 2 1
    2 3 1
    1 1

  lower_plate ss  5.0 0.5   ! mat, thickness, vol frac
  upper_plate ss  7.6 0.5
```

QST#4
Input – [CORE]

assm_map	3 2 3 3 2 1 2 3 1 1 1	octant symmetry map of assembly types, as defined in ASSEMBLY block




```
[CORE]
  size   9                  ! assemblies across core
  apitch 23
  rated  1007.19 38.9       ! MW, Mlbs/hr
  height 306.337

  core_shape
     0 0 0 1 1 1 0 0 0
     0 0 1 1 1 1 1 0 0
     0 1 1 1 1 1 1 1 0
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     1 1 1 1 1 1 1 1 1
     0 1 1 1 1 1 1 1 0
     0 0 1 1 1 1 1 0 0
     0 0 0 1 1 1 0 0 0

  assm_map

    3
    2 3
    3 2 1
    2 3 1
    1 1

  lower_plate ss  5.0 0.5   ! mat, thickness, vol frac
  upper_plate ss  7.6 0.5
```

Today we'd like to try a different core loading pattern where the lower enriched fuel is located on the core periphery. Modify your input, swapping the positions of type 1 and type 3 assemblies.

QST#4 Output

View your output on Titan as it is computed:

type *tail –f {job #}*

```
000:00.01 Processing Input...
000:00.34 Processing XS Libraries...
000:01.15 Generating Materials...
000:01.17 Generating Reactor Geometry...
000:01.18 Generating Reactor Mesh...
000:06.37 Initializing Parallel Environment...
000:06.37 Setting up angular quadrature...
000:06.37 Initializing mesh...
000:06.40 Generating Input Edits...
              Setting up modular rays...
              Performing ray tracing...
000:07.11 Initializing Base MOC Sweeper...
              Setting up long rays...
000:07.12 Initializing PS 2D1D Sweeper...
                    ...with LFLAT axial TL spatial treatment
                    ...with ISO axial TL angular treatment
                    ...with axial TL splitting
000:07.12 Initializing Multi-group Fixed Source Solver...
000:08.27 Initializing Eigenvalue Solver...
              Adding eigenvalue accelerator...
               -CMFD acceleration is being used (1G LS)
                    ...with PO boundary update
                    ...not using angle decomp processors
000:08.76 Initializing Equilibrium Xenon Calculation...
000:08.77 Initializing Feedback Solver...
000:08.78 Initializing MultiState Solver...
001:26.43 Solving State 1/1...
001:26.43 Computing Equilibrium Xenon Concentration...
001:31.18 Using TCPO in All Regions...
001:31.18 Performing Eigenvalue Calculation...
001:31.18      iter     keff      norm_keff     norm_fissrc
001:31.18         0  1.0000000 9.990000E-01 9.990000E-01
          MG-CMFD   10  1.0879996 5.584375E+01
          MG-CMFD   20  1.1152087 2.987059E+01
          MG-CMFD   30  1.1261371 1.956113E+01
          MG-CMFD   40  1.1308703 1.386926E+01
          MG-CMFD   50  1.1330909 1.030431E+01
          MG-CMFD   60  1.1342211 7.955864E+00
          MG-CMFD   70  1.1348425 6.354747E+00
          MG-CMFD   80  1.1352085 5.221314E+00
          MG-CMFD   90  1.1354366 4.384074E+00
          MG-CMFD  100  1.1355846 3.738767E+00
          MG-CMFD  110  1.1356829 3.222572E+00
          MG-CMFD  120  1.1357487 2.797453E+00
          MG-CMFD  130  1.1357923 2.439863E+00
          MG-CMFD  140  1.1358203 2.134649E+00
          MG-CMFD  150  1.1358374 1.871571E+00
          MG-CMFD  160  1.1358466 1.643325E+00
          MG-CMFD  170  1.1358502 1.444437E+00
          MG-CMFD  180  1.1358500 1.270621E+00
          MG-CMFD  190  1.1358472 1.118414E+00
          MG-CMFD  200    71    1.1358427   9.849434E-01
          1G-INNER   1          94          2.365391E-01
008:20.49 Computing Equilibrium Xenon Concentration...
008:34.24 Using TCPO in All Regions...
008:34.24         1  1.1358427 1.358427E-01 4.106636E+00
          MG-CMFD    1    71    1.1255560   3.286467E+01
          1G-INNER   1          94          1.141620E-02
011:40.43         2  1.1255560 1.028663E-02 7.622226E-02
011:40.43 Convergence criteria satisfied
011:40.50 Finished
```

keff

QST#4 Output

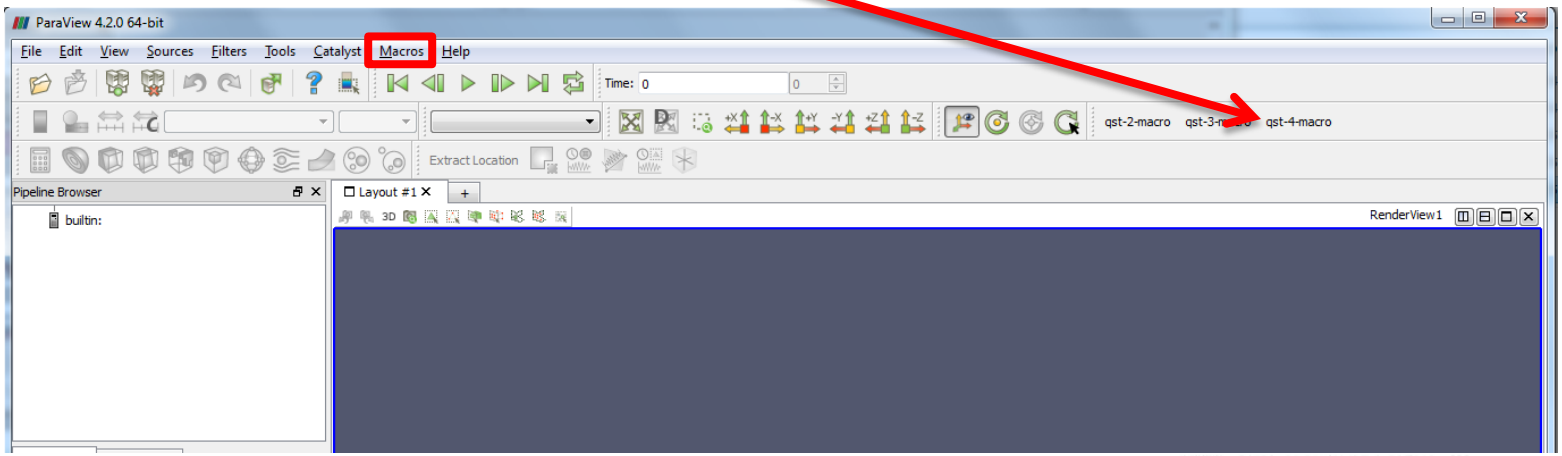
```
==============================================================================
                     Axially-Integrated 2-D Assembly Powers
==============================================================================
y/x       1       2       3       4       5
  1  2.6832  2.2360  1.8077  0.9414  0.2752
  2  2.2360  2.1821  1.4260  0.8116  0.1759
  3  1.8077  1.4260  0.7768  0.2666  0.0000
  4  0.9414  0.8116  0.2666  0.0000  0.0000
  5  0.2752  0.1759  0.0000  0.0000  0.0000
==============================================================================
                       Axially-Integrated 2-D Pin Powers
==============================================================================
Assembly   1 at (  1,  1)
y/x       1       2       3       4       5       6       7       8       9
  1  0.0000  2.7054  2.7160  0.0000  2.6928  2.6874  0.0000  2.6348  2.6305
  2  2.7054  2.7832  2.7750  2.7392  2.7611  2.7437  2.6947  2.6982  2.6567
  3  2.7160  2.7750  2.7651  2.7497  2.7664  2.7368  2.7045  2.7003  2.6744
  4  0.0000  2.7392  2.7497  0.0000  2.7454  2.7424  0.0000  2.7053  2.6301
  5  2.6928  2.7611  2.7664  2.7454  2.8244  2.7926  2.7844  2.6435  2.6098
  6  2.6874  2.7437  2.7368  2.7424  2.7926  0.0000  2.6413  2.5802  2.5975
  7  0.0000  2.6947  2.7045  0.0000  2.7844  2.6413  2.5969  2.5750  2.5334
  8  2.6348  2.6982  2.7003  2.7053  2.6435  2.5802  2.5750  2.4790  2.5334
  9  2.6305  2.6567  2.6744  2.6301  2.6098  2.5975  2.5334  2.5334  2.5454
Assembly   2 at (  2,  1)
y/x       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15      16      17
  1  2.3220  2.3733  0.0000  2.4144  2.3970  0.0000  2.3667  2.3284  0.0000  2.2751  2.2563  0.0000  2.1921  2.1537  0.0000  2.0295  1.9360
  2  2.3490  2.4201  2.4283  2.4573  2.4510  2.4102  2.4086  2.3876  2.3013  2.3288  2.2999  2.2507  2.2377  2.1942  2.1214  2.0663  1.9611
  3  2.3601  2.4231  2.4356  2.4503  2.4559  2.4194  2.4002  2.3829  2.3099  2.3240  2.2918  2.2583  2.2412  2.1886  2.1269  2.0687  1.9695
  4  2.3214  2.4257  0.0000  2.4572  2.4369  0.0000  2.3937  2.3553  0.0000  2.3009  2.2816  0.0000  2.2280  2.1911  0.0000  2.0736  1.9352
  5  2.3095  2.3703  2.4948  2.4930  2.4959  2.4112  2.4001  2.3699  2.2901  2.3111  2.2910  2.2506  2.2763  2.2253  2.1785  2.0224  1.9263
  6  2.2904  2.3177  2.3720  0.0000  2.4657  2.4010  2.3684  2.3491  2.2775  2.2907  2.2605  2.2396  2.2486  0.0000  2.0711  1.9757  1.9079
  7  2.2329  2.3004  2.3207  2.3465  2.4381  0.0000  2.3290  2.2933  0.0000  2.2396  2.2189  0.0000  2.2260  2.0922  2.0240  1.9608  1.8562
  8  2.2307  2.1984  2.2754  2.2637  2.2904  2.3193  2.2881  2.2604  2.1900  2.2040  2.1834  2.1627  2.0882  2.0196  1.9807  1.8689  1.8542
  9  2.2166  2.2064  2.1808  2.2123  2.2062  2.1906  2.2023  2.1686  2.1152  2.1139  2.1011  2.0429  2.0101  1.9701  1.8970  1.8729  1.8377
Assembly   3 at (  3,  1)
y/x       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15      16      17
  1  2.1411  2.0887  0.0000  2.0383  1.9902  0.0000  1.9221  1.8655  0.0000  1.7777  1.7380  0.0000  1.6487  1.5987  0.0000  1.4932  1.4452
  2  2.1592  2.1419  2.0886  2.0783  2.0437  1.9807  1.9602  1.9223  1.8209  1.8247  1.7788  1.7147  1.6862  1.6344  1.5651  1.5253  1.4619
  3  2.1734  2.1428  2.0959  2.0715  2.0476  1.9882  1.9525  1.9163  1.8269  1.8185  1.7717  1.7195  1.6878  1.6298  1.5691  1.5257  1.4700
  4  2.1384  2.1421  0.0000  2.0779  2.0267  0.0000  1.9439  1.8871  0.0000  1.7968  1.7572  0.0000  1.6766  1.6284  0.0000  1.5294  1.4424
  5  2.1183  2.0950  2.1537  2.1112  2.0878  1.9816  1.9506  1.9035  1.8088  1.8058  1.7682  1.7129  1.7177  1.6580  1.6122  1.4894  1.4305
  6  2.1077  2.0442  2.0403  0.0000  2.0616  1.9776  1.9270  1.8888  1.8013  1.7913  1.7461  1.7067  1.6956  0.0000  1.5266  1.4499  1.4193
  7  2.0557  2.0357  2.0043  1.9925  2.0493  0.0000  1.9041  1.8484  0.0000  1.7583  1.7186  0.0000  1.6891  1.5607  1.4963  1.4439  1.3785
  8  2.0498  1.9596  1.9866  1.9405  1.9436  1.9436  1.8936  1.8492  1.7590  1.7532  1.7143  1.6755  1.5972  1.5217  1.4768  1.3828  1.3759
  9  2.0571  1.9993  1.9494  1.9513  1.9151  1.8834  1.8700  1.8164  1.7502  1.7203  1.6923  1.6237  1.5708  1.5240  1.4474  1.4076  1.3756
```

- To view pin powers, vi or list the .out file, qst-3.out (in vi, search for “Axially” by typing /Axially)

QST#2
Visualizing the Results

ParaView

1. Transfer the qst-4.silo file from Titan to your machine or your USB drive (see handout)
2. Open ParaView from USB drive
3. Open file qst-4.silo
4. Click Macros from main toolbar
5. Select “Add new macro…
6. From the USB drive in the “macro” folder, select “qst-4-macro.py” and open
7. Click “qst-4-macro” on toolbar



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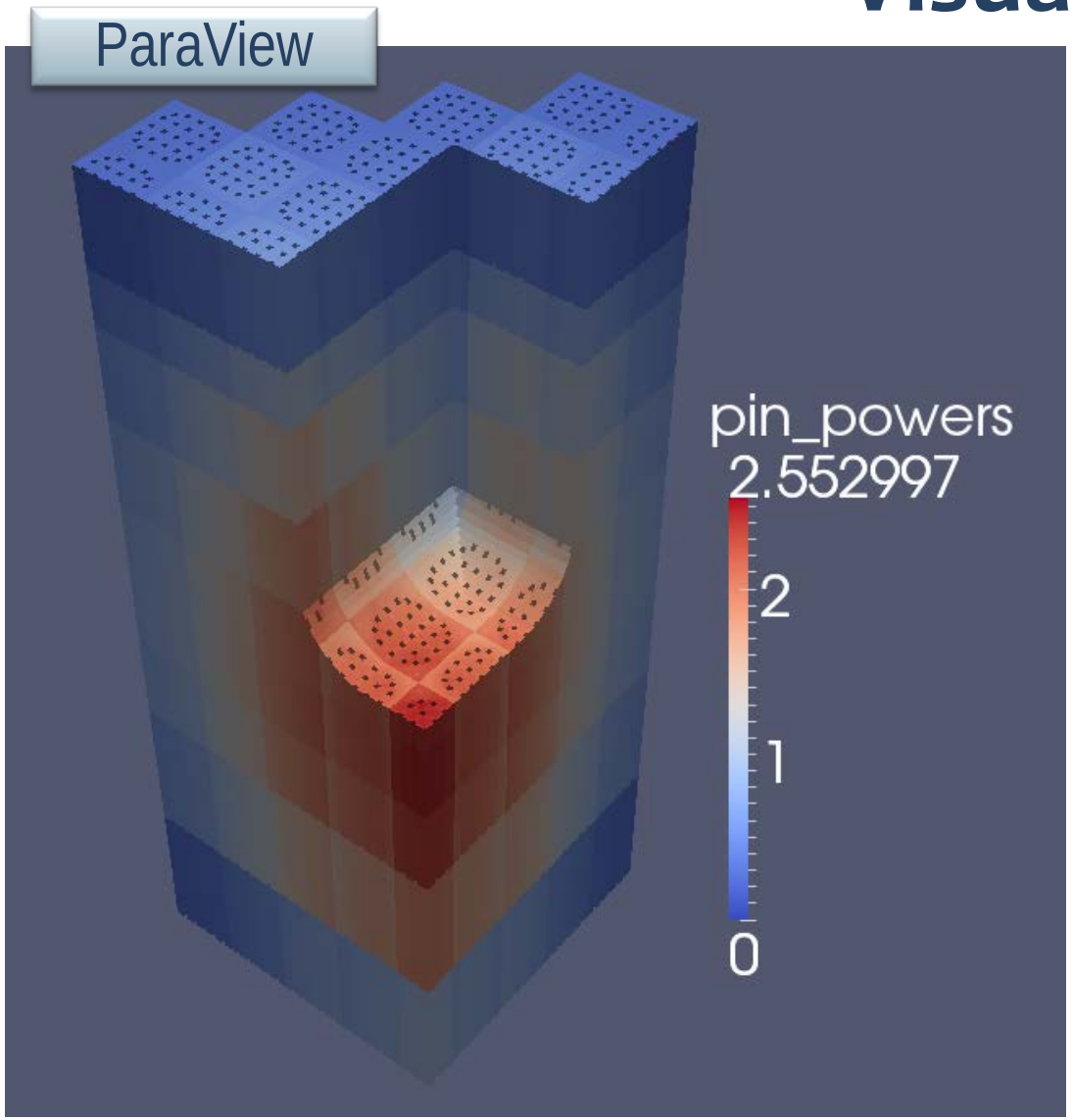
QST#4 Visualization



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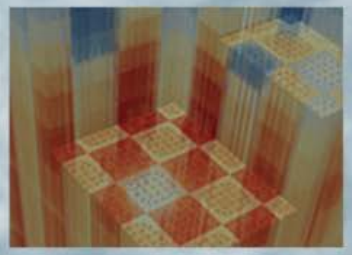
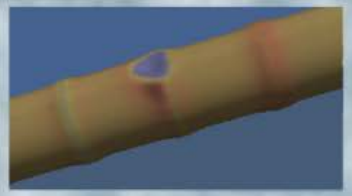
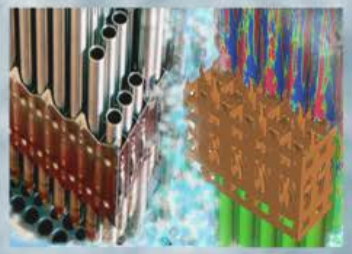


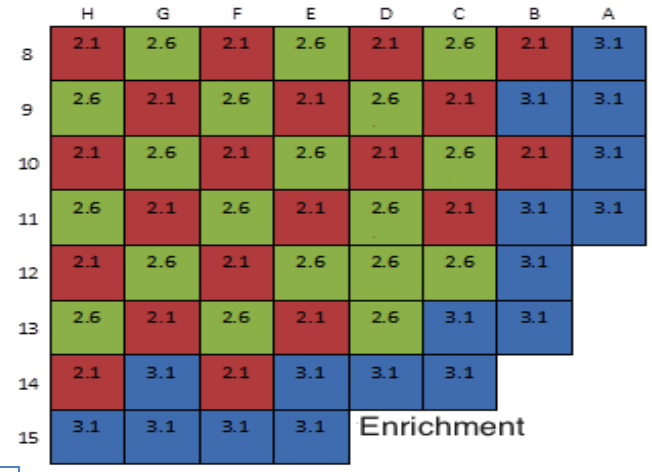


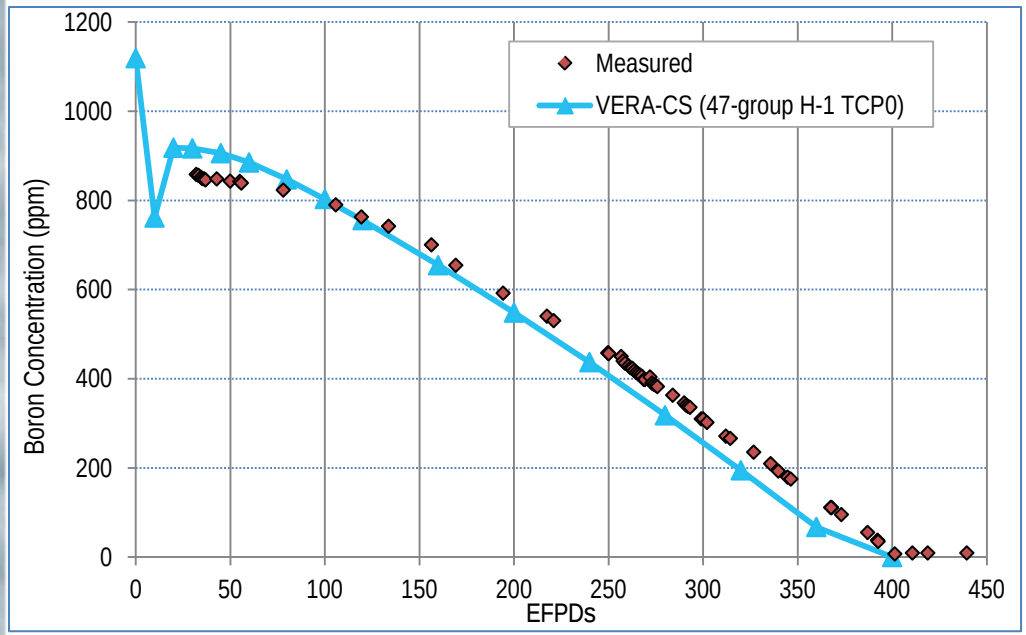


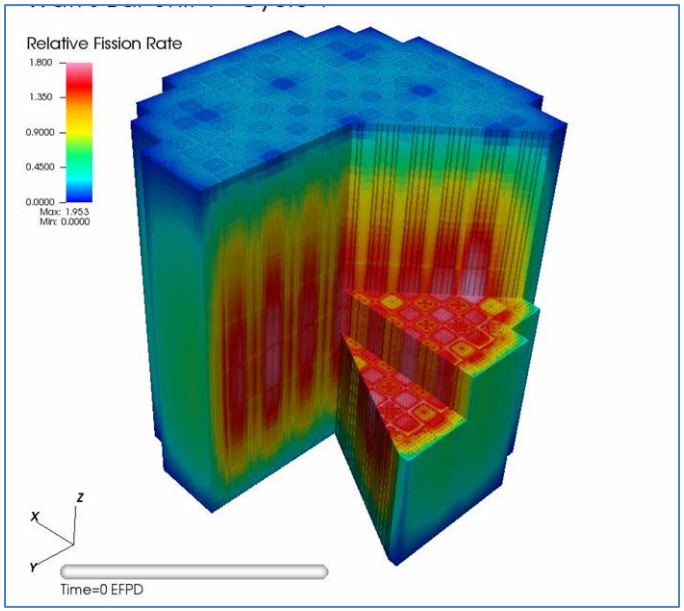
VERA Demonstration: Westinghouse 4-loop reactor 3D with thermal-hydraulic feedback

Quick Start Tutorial # 5 Full Core

- Watts Bar Unit 1 Cycle 1 Depletion
- From BOC HZP to EOC
  - 441 EFPD
- 32 state points
- High fidelity solution







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QST# 5
Control Rods

- Control rods need to be specified in three blocks

  [STATE] – describes the bank (for that state)

  [CORE] – describes the locations in the core

  [CONTROL] – specifies geometry and makeup of rods (very similar to ASSEMBLY block)

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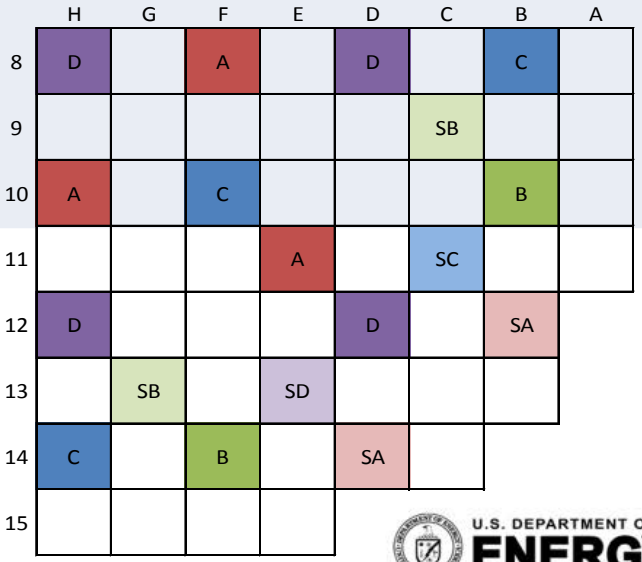
QST#5 Input – [CORE]

Input parameter	Value	Description
crd_map	1 - - 1 - 1 - - - 1 1 - - - 1 - 1 - 1 - - 1 - 1 - 1 - - - - -	map indicating rod locations (octant core symmetry) A “dash” represents an assembly location without a control rod
crd_bank	D - A - D - C - - - - - - SB - - A - C - - - B - - - - A - SC - - D - - - D - SA - SB - SD - - - C - B - SA - - - - -	map of specific control rod banks (quarter core symmetry)



QST#5
Input – [CONTROL]

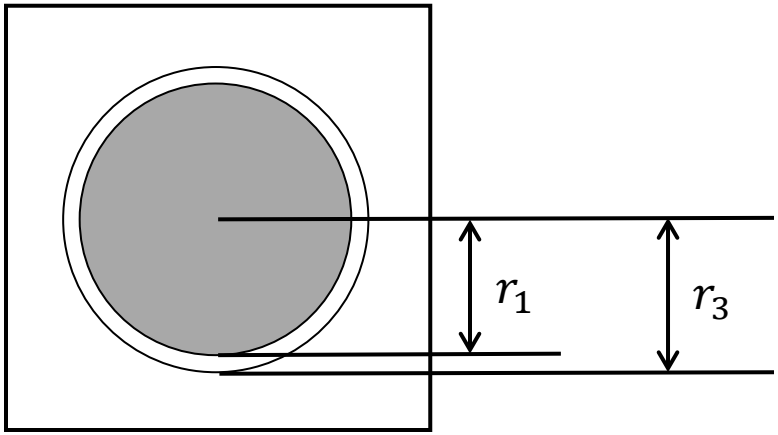
Input parameter	Value	Description
npin	17	# of pins
stroke	365.125 230	distance between fully inserted and fully withdrawn (cm); total # of rod steps.

QST#5
Input – [CONTROL]

cell	A	0.382	0.386	0.484	/	aic	he	ss	
cell	B	0.373	0.386	0.484	/	b4c	he	ss	
cell	P		0.386	0.484	/		he	ss	→ plenum
cell	G			0.484	/			ss	→ end plug

radii

materials




```
[CONTROL]
  title "B4C with AIC tips"
  npin 17
  stroke  365.125 230     ! approx for 1.5875 step

  cell A  0.382 0.386 0.484 / aic he ss
  cell B  0.373 0.386 0.484 / b4c he ss
  cell P        0.386 0.484 /     he ss ! plenum
  cell G              0.484 /        ss ! plug

  rodmap AIC
     -
     - -
     - - -
     A - - A
     - - - - -
     - - - - - A
     A - - A - - -
     - - - - - - - -
     - - - - - - - - -
```

QST#5
Input – [CONTROL]

```
rodmap AIC
   -
   - -
   - - -
   A - - A
   - - - - -
   - - - - - A
   A - - A - - -
   - - - - - - - -
   - - - - - - - - -
```

aic cell

empty

```
rodmap B4C
   -
   - -
   - - -
   B - - B
   - - - - -
   - - - - - B
   B - - B - - -
   - - - - - - - -
   - - - - - - - - -
```

```
rodmap PLEN
   -
   - -
   - - -
   P - - P
   - - - - -
   - - - - - P
   P - - P - - -
   - - - - - - - -
   - - - - - - - - -
```

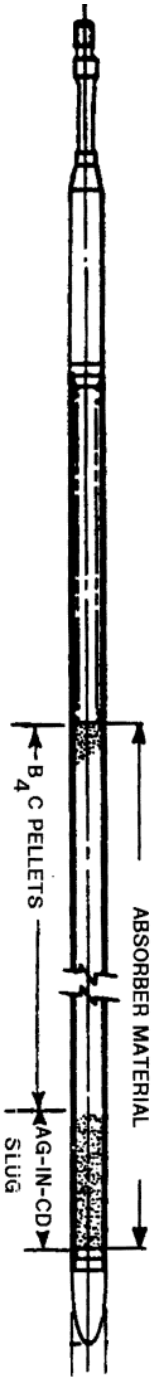
```
rodmap PLUG
   -
   - -
   - - -
   G - - G
   - - - - -
   - - - - - G
   G - - G - - -
   - - - - - - - -
   - - - - - - - - -
```

cell	A	aic
cell	B	b4c

cell	P	plenum
cell	G	plug

QST#5
Input – [CONTROL]

Parameter	Label	height (cm)
axial	1	15.131
	PLUG	17.031
	AIC	118.631
	B4C	377.711
	PLEN	388.411
	PLUG	390.311




```
rodmap PLEN
   -
   - -
   - - -
   P - - P
   - - - - -
   - - - - - P
   P - - P - - -
   - - - - - - - -
   - - - - - - - - -

rodmap PLUG
   -
   - -
   - - -
   G - - G
   - - - - -
   - - - - - G
   G - - G - - -
   - - - - - - - -
   - - - - - - - - -

axial  1     15.131
      PLUG  17.031
       AIC 118.631
       B4C 377.711
      PLEN 388.411
      PLUG 390.311

[DETECTOR]
  title "Pyrex"
  npin 17

  cell x  0.214 0.231 0.241 0.427 0.43
```

QST#5
Input – [STATE]

Input parameter	Value	Description
rodbank	SA 230 SB 230 SC 230 SD 230 A 230 B 230 C 230 D 186	control rod bank name and number of steps withdrawn (0 is fully inserted)

- Control rod <u>moves</u> can be added by including a new [STATE] block
- For example:

```
[STATE]
  title    'Case 23'
  power          98.0
  tinlet         557.6
  rodbank      D 215
  deplete   EFPD 226.8
[STATE]
  title    'Case 24'
  power          99.4
  tinlet         557.7
  rodbank      D 220
  deplete   EFPD 247.8
[STATE]
  title    'Case 25'
  power          99.9
  tinlet         557.8
  rodbank      D 219
  deplete   EFPD 273.2
```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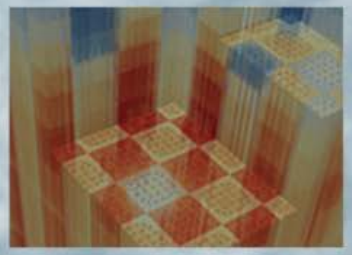
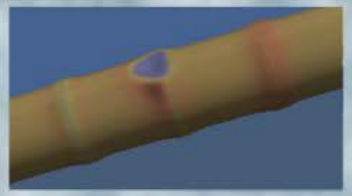
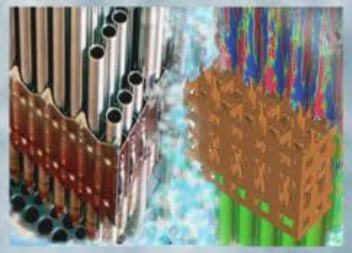
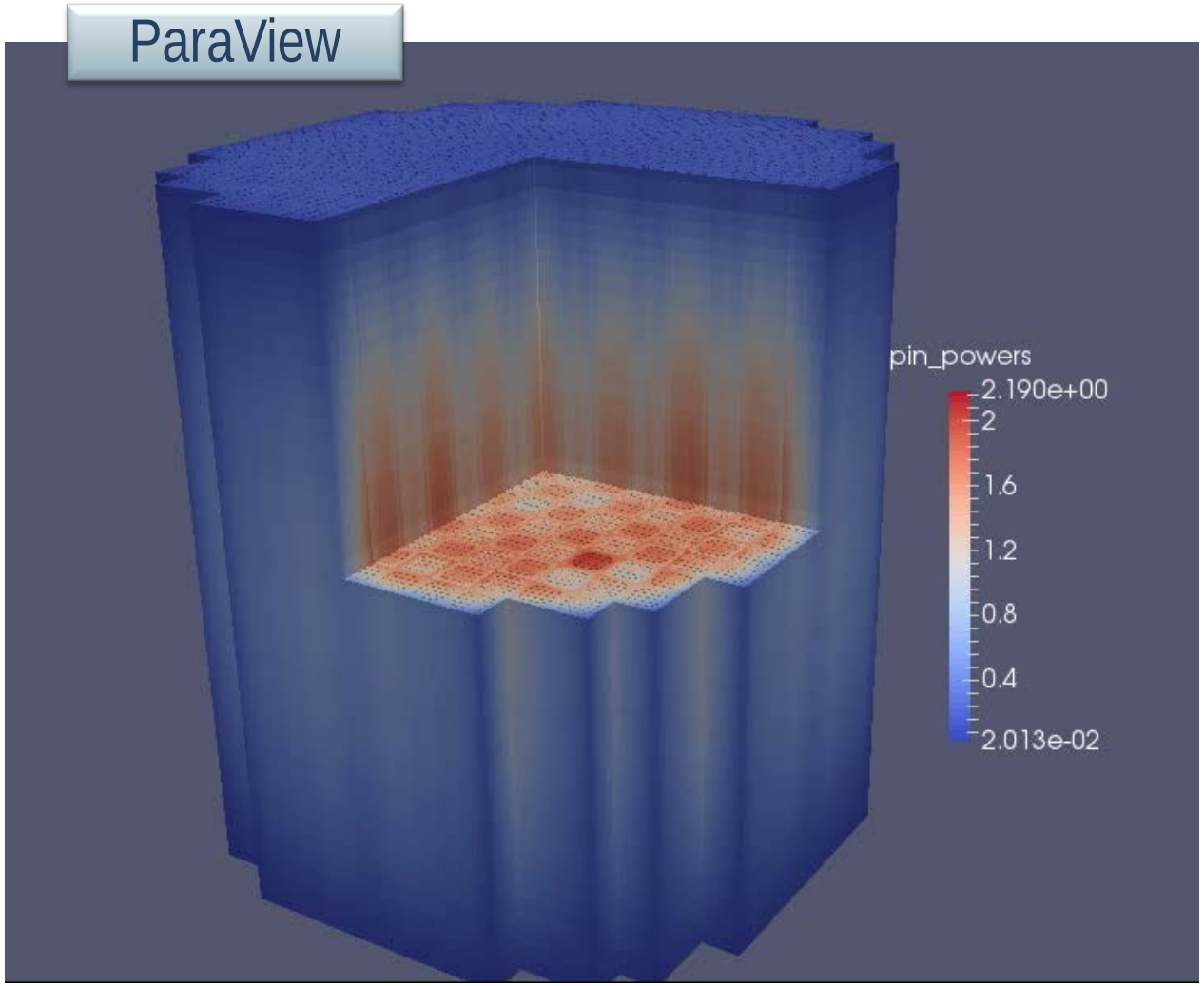
RESULTS







QST#5 Visualization



References

- CASL-U-2012-0131-004 “VERA Core Physics Benchmark Progression Problem Specifications.” Andrew T. Godfrey, Aug. 2014
- CASL-U-2014-0014-002 “VERA Common Input User Manual.” Palmtag, Scott and Andrew Godfrey, February 23, 2015.
- CASL-U-2015-055-000 “CTF – A Thermal-Hydraulic Subchannel Code for LWRs Transient Analysis, User’s Manual, Revision 0.” Avramova, Maria N. and Robert K. Salko, March 10, 2015.
- CASL-U-2015-0043-000, “MPACT VERA Common Input User’s Manual Version 2.0.” Benjamin Collins et.al., February 20, 2015.

Your Feedback is important to us!

- Please fill out a feedback survey before you leave
- Also, please remember to turn in your RSA token before you leave!

Thank you for attending!

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Contact Info

- Website:
  - www.casl.gov
- VERA questions:
  - support@casl.gov
- Bugs, enhancement requests:
  - support@casl.gov
- CASL / VERA News:
  - To subscribe, send email to CASL-update@casl.gov with “subscribe” in the subject.
- Join the VERA Working Group
  - A User Portal website is being developed
  - Look for an invitation later this year

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