INL/CON-23-70872-Revision-1

Replacement of Legacy Analytical Codes at the Advanced Test Reactor

June 2023

Changing the World's Energy Future

Nathan Manwaring

Idaho National Laboratory

INL/CON-23-70872-Revision-1

Replacement of Legacy Analytical Codes at the Advanced Test Reactor

Nathan Manwaring

June 2023

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

June 2023

Nathan Manwaring
Advanced Test Reactor
Reactor Engineering

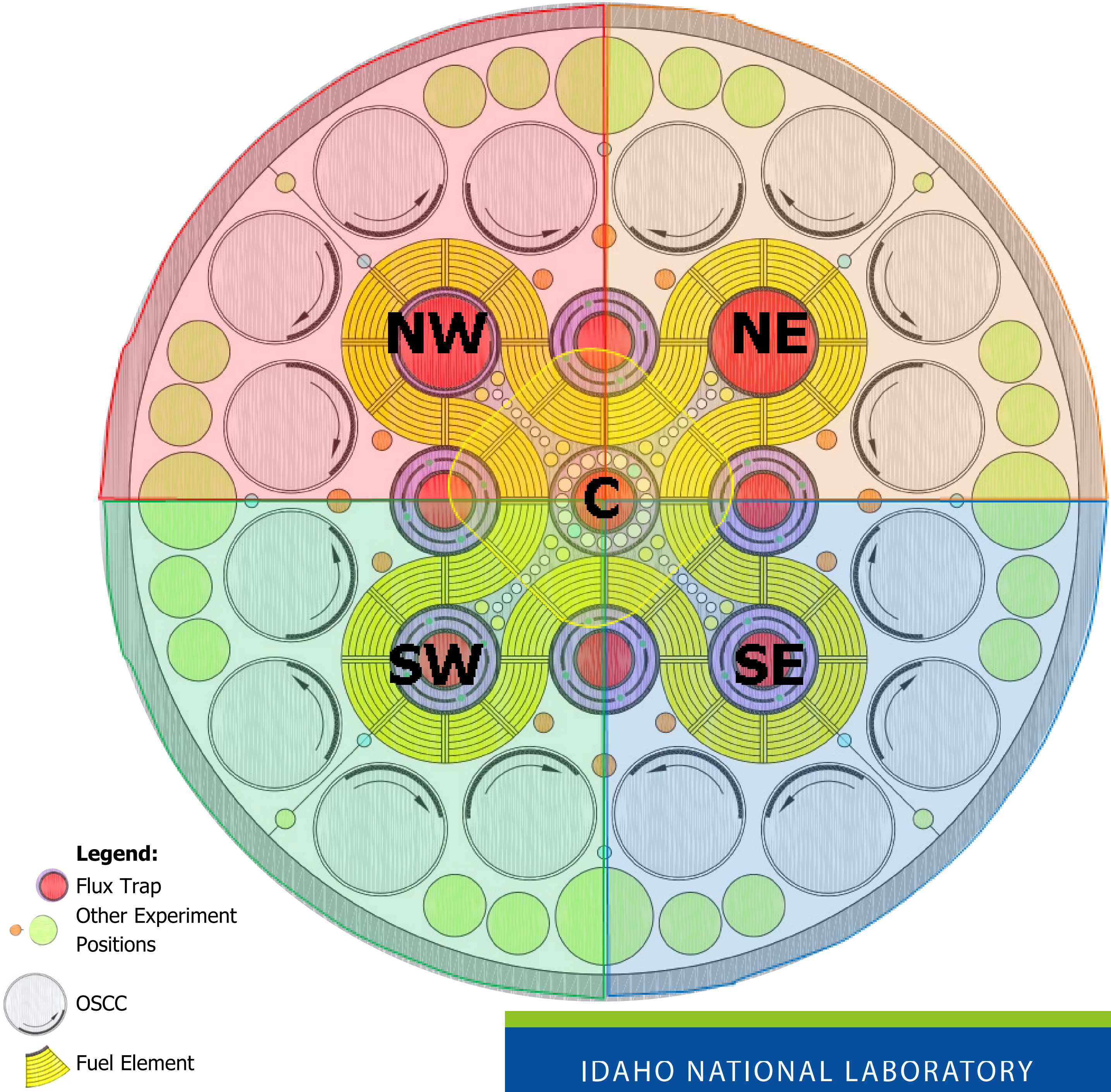
Replacement of Legacy Analytical Codes at the Advanced Test Reactor

Outline

- Introduction to Advanced Test Reactor (ATR)
  - Idaho National Laboratory
  - Fuel Arrangement
  - Flux Traps
- Software Replacement
  - DEV2 Computer
  - Fuel Δρ
  - Cycle Surveillance
  - Power Division

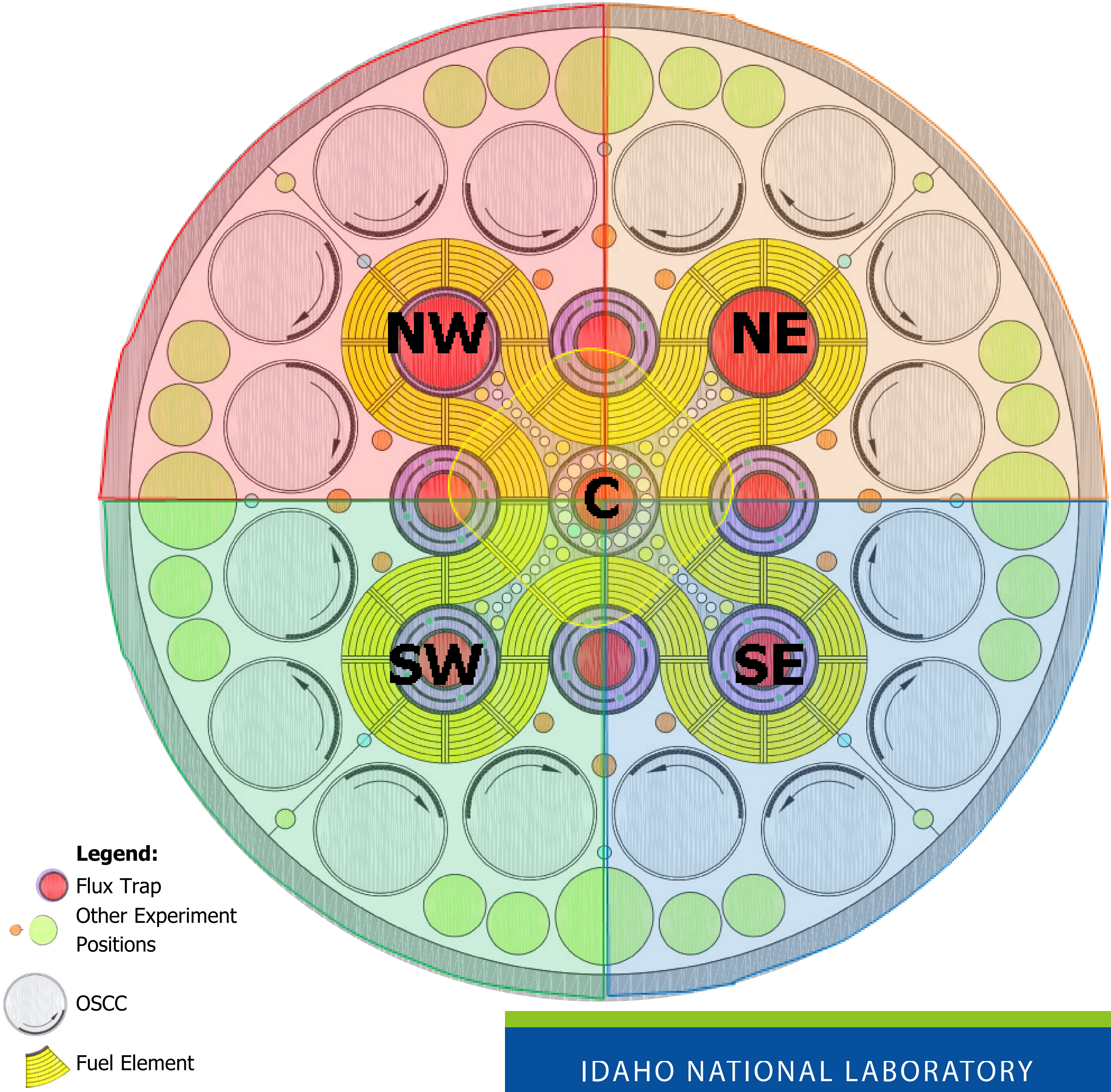
Introduction to ATR

- More than 70 test positions
  - 9 flux traps
  - 6 (of the 9) have loops
    - Independent Chemistry, temperature, and pressure
- Control Elements
  - 6 Safety Rods (annular)
  - 16 Outer Shim Control Cylinders (OSCCs)
  - 22 Neck Shims
    - +2 Regulating Rods
- 40 Fuel Elements
  - 19 plates
  - 48” (120cm) active length
  - Serpentine arrangement



Introduction to ATR

- Design Summary
  - 250 MW_{th} (Typically 110MW_{th})
  - Max thermal flux:
    - 10^{15} n/cm^2-s
  - Max fast flux:
    - 5×10^{14} n/cm^2-s
- Companion ATRC
  - 5 kW_{th}
  - Pool type

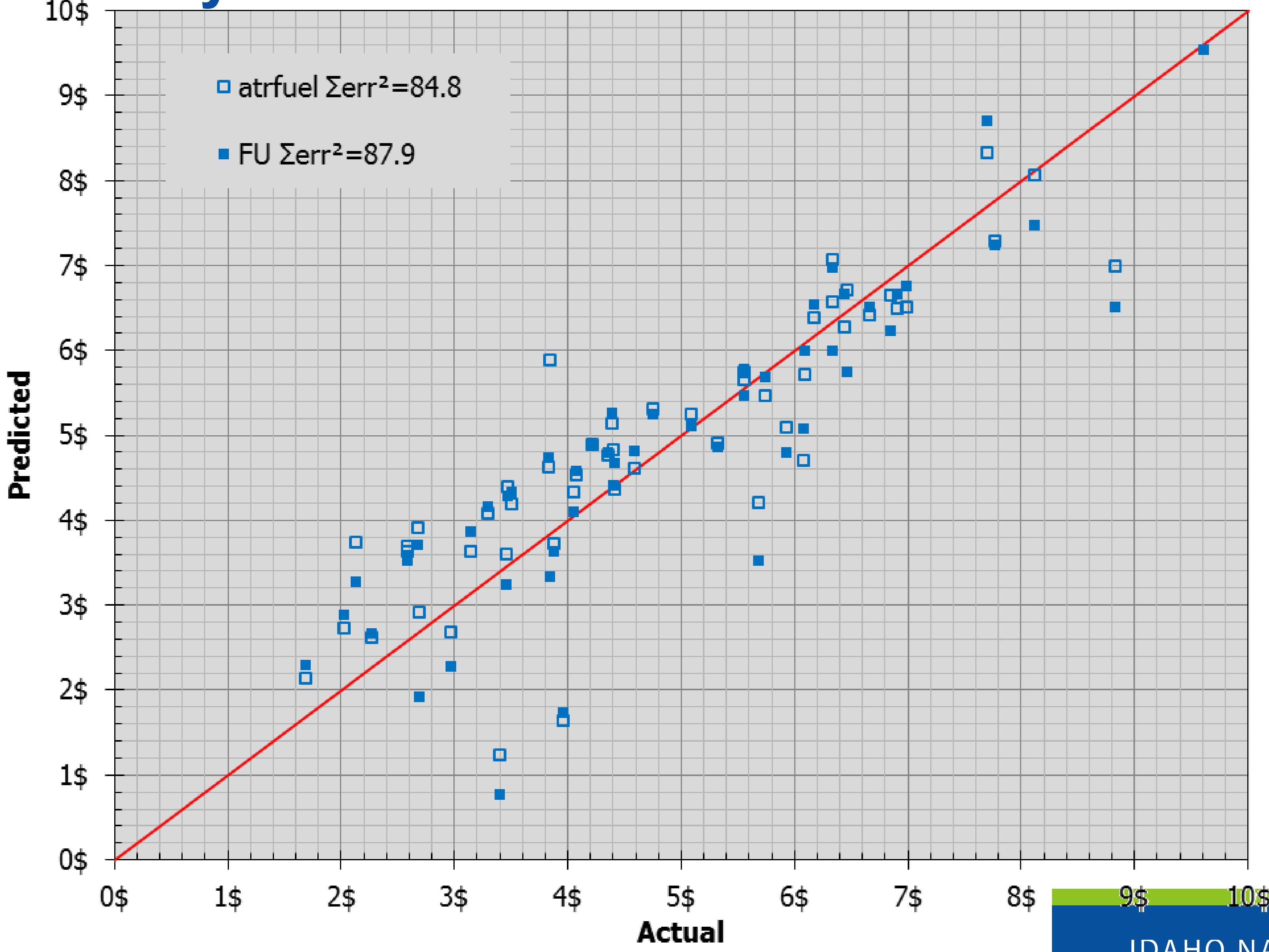


“FU” Database

- Simple
  - ^{235}U (g)
  - ^{10}B(g)
  - ^{149}Sm (atoms)
  - Exposure (MWd)
- Hard to use
  - One VAX/VMS computer
  - No configuration control
- Parallel to other databases

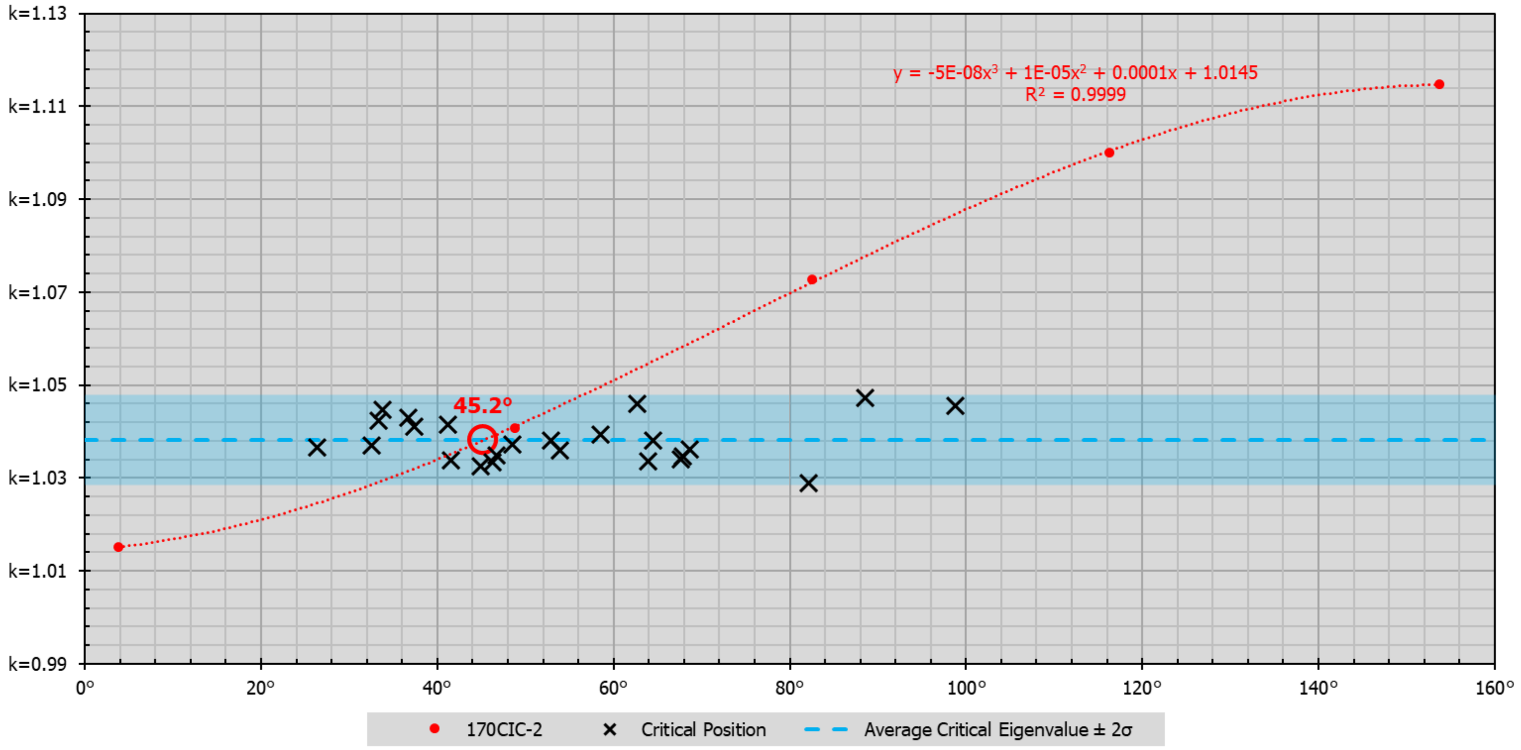
```
NEW NB ELEMENTS--XAxxxTNB
XA771TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA772TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA773TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA774TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA775TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA776TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA777TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA785TNB  1075.0000 0.0000000 0.0000E+00    0 NONE
XA786TNB  1075.0000 0.0000000 0.0000E+00    0 NONE

END OF NEW INVENTORY
------------------------------------------------------------------------
           CYCLE 052A-1
LMWDs OF CYCLE:     562.      614.      813.      662.      871.

           CYCLE 158A-1                    DATE  4-FEB-14
LMWDs OF CYCLE:        941.3     994.2     1112.1    1044.2    1410.0
XA099U      878.7416 0.1526428 0.4435E+21  941 NONE
XA125U      723.1025 0.0436525 0.3897E+21 2087 NONE
XA922T      791.6274 0.0757487 0.3450E+21 1824 NONE
XA082U      777.6970 0.0677196 0.2858E+21 1933 NONE
XA134U      979.9610 0.3445471 0.3170E+21  941 NONE
YA559TM     792.5179 0.0754971 0.3246E+21 1622 NONE
XA129U      774.4969 0.0659988 0.3658E+21 1841 NONE
XA135U      896.8165 0.1765283 0.4209E+21  941 NONE
XA853T      598.2222 0.0159877 0.3952E+21 3198 NONE
XA803T      675.0710 0.0296639 0.3537E+21 2472 NONE
XA614TNB    657.7376 0.0000000 0.2971E+21 2762 NONE
YA554TM     693.4238 0.0314208 0.2635E+21 2950 NONE
XA839T      698.9895 0.0359567 0.2667E+21 3200 NONE
YA543TM     586.4107 0.0121921 0.3048E+21 2676 NONE
XA033U      620.0419 0.0190548 0.3993E+21 2367 NONE
XA077U      639.0870 0.0222092 0.4415E+21 2633 NONE
XA074U      729.1852 0.0458413 0.3358E+21 2076 NONE
XA081U      724.5605 0.0441674 0.3668E+21 2076 NONE
XA629TNB    697.3740 0.0000000 0.3912E+21 2016 NONE
XA128U      680.2374 0.0309226 0.3978E+21 2258 NONE
```

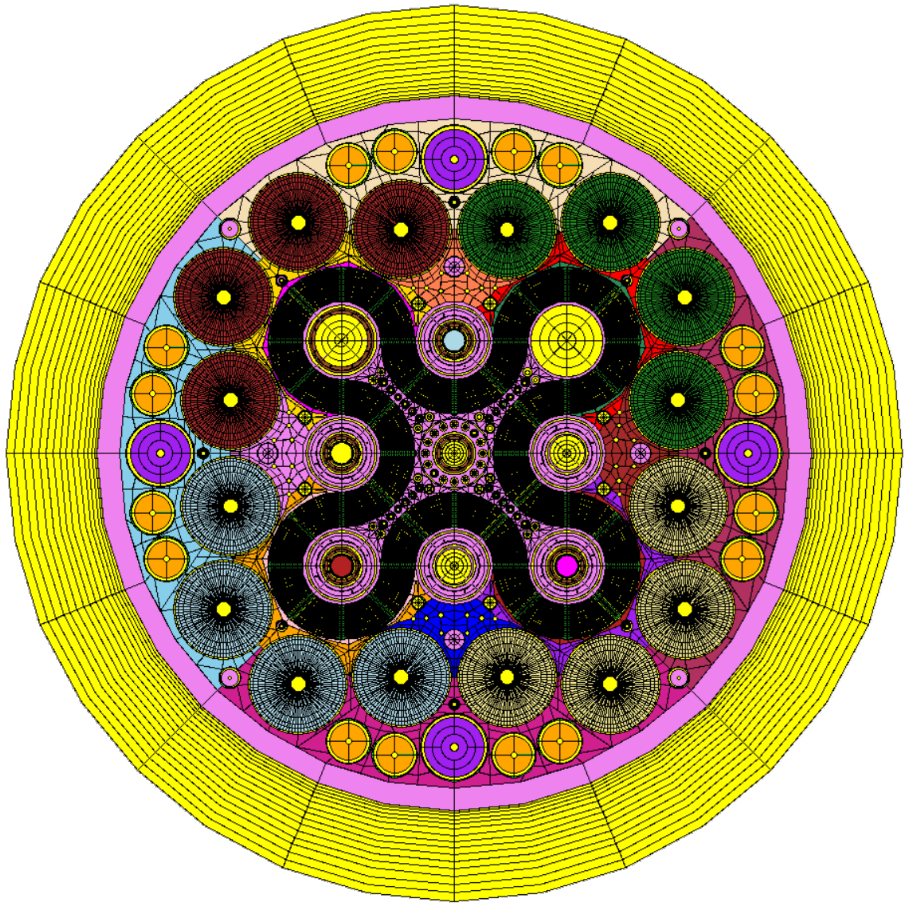
Core Reactivity Prediction



Core Reactivity from Helios Model

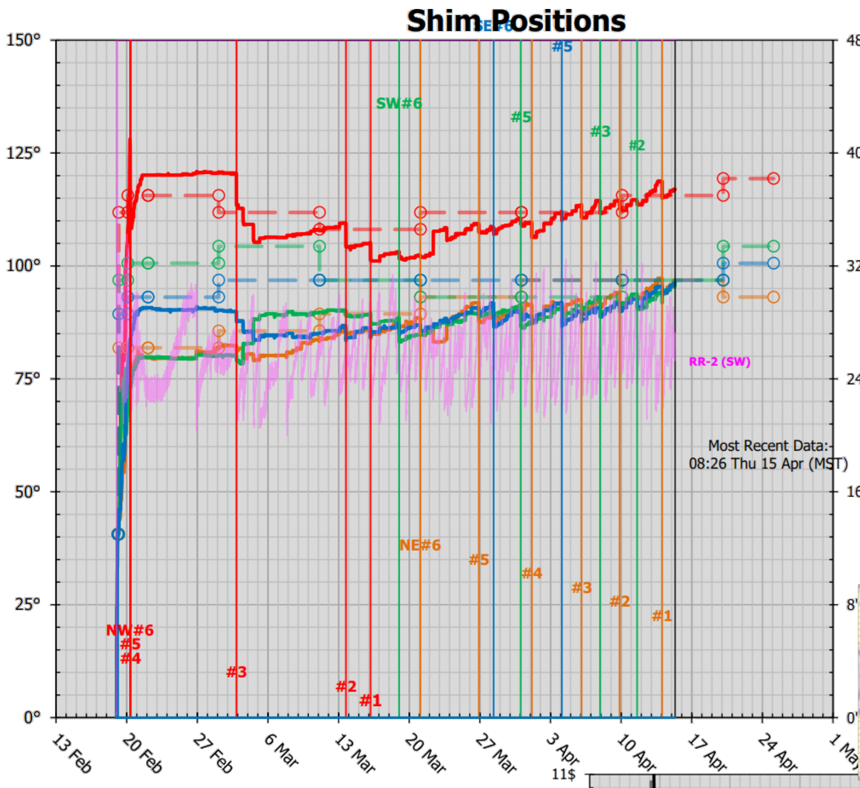
- Model: ≈45.2°
- ATRC: ≈57.2°
- Actual: 57.3°

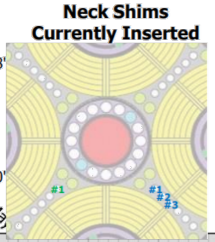


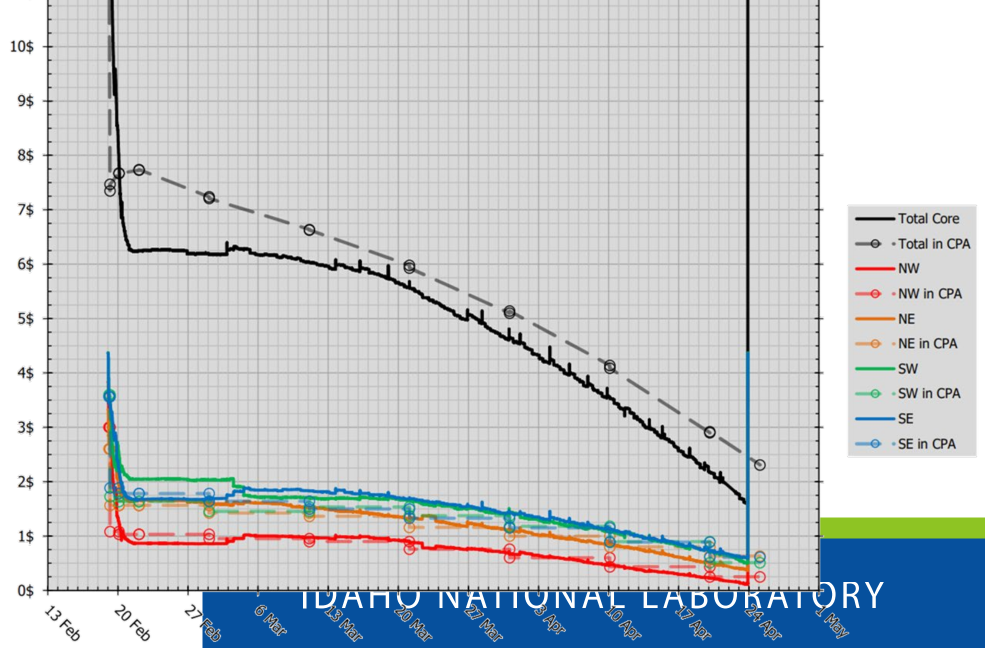


Surveillance Files

- Old Tools:
  - Text file
  - One datum per hour
  - VAX/VMS
- New Tools:
  - Plots
  - Millisecond resolution
  - User can calculate anything, such as Core Excess Reactivity
  - User's choice
    - Visual Basic / Excel
    - MATLAB
    - Python

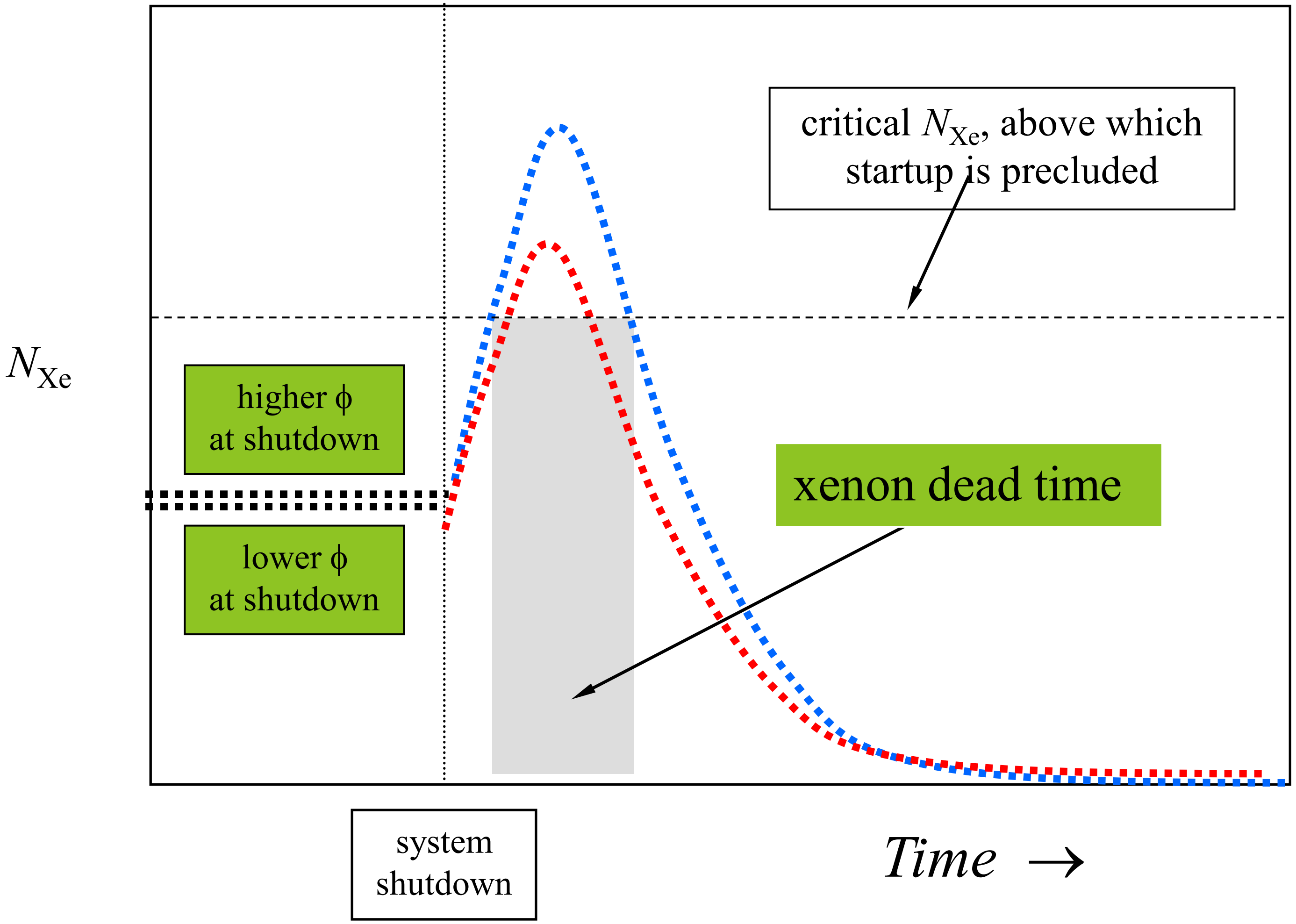






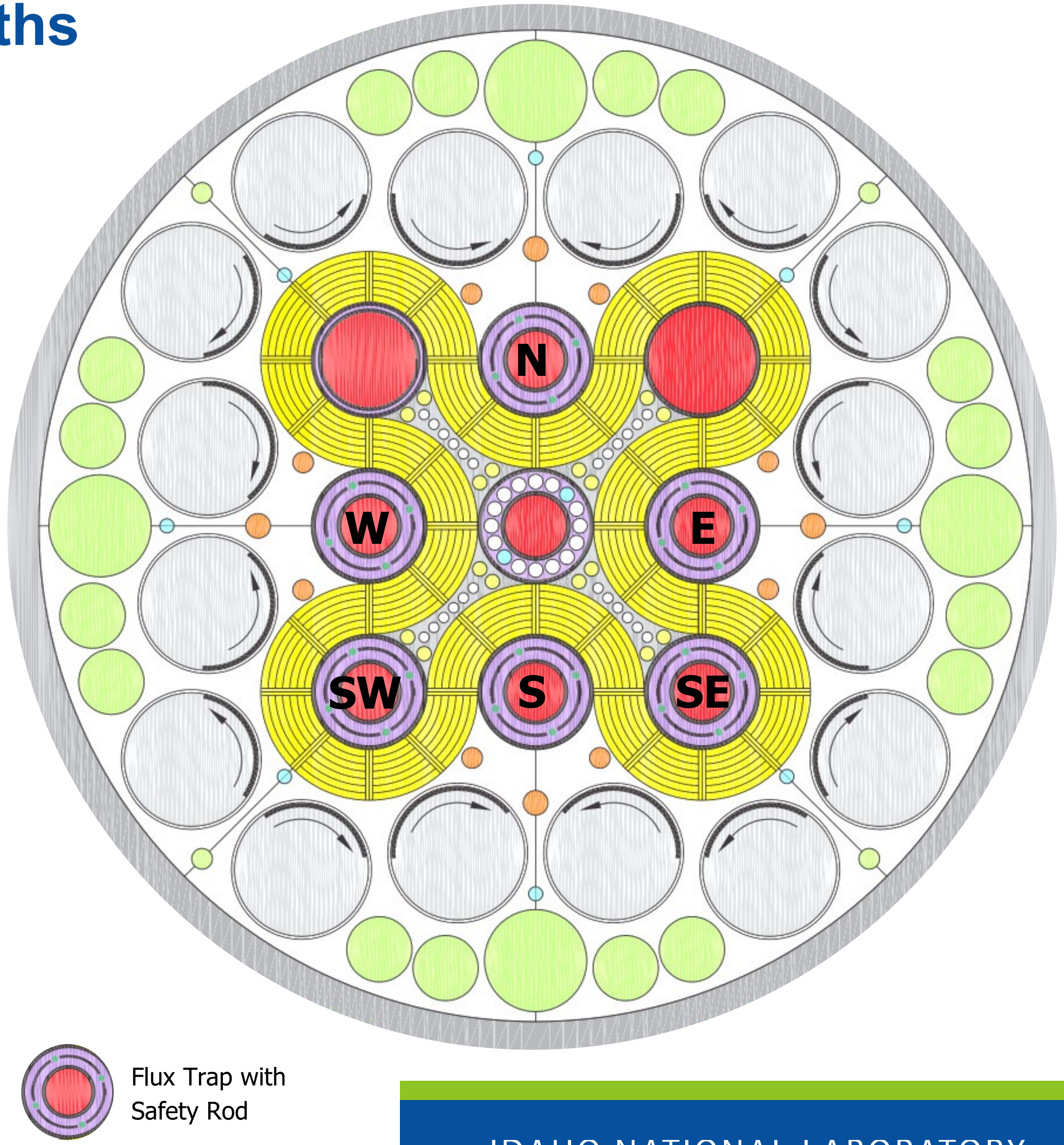
Surveillance Files

- ^{135}Xe Transients
  - Rules of thumb to cover decrease
    - Frequent experience
  - Can't support restart during buildup transient
    - Not done at ATR since 1990s



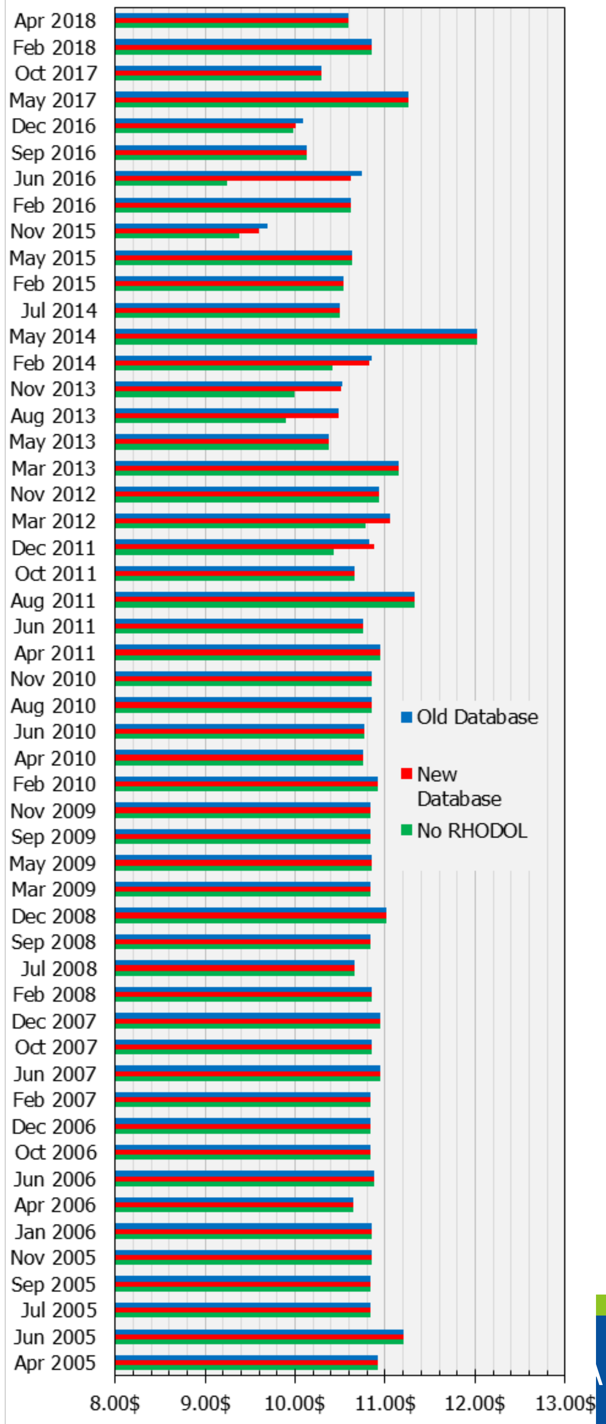
Power Divisions – Safety Rod Worths

- Depends on local relative power
- Absorber transients during restart
  - Balanced OSCCs
  - Quick Restart:
    Operating ^{135}Xe burden
  - Delayed Restart:
    Estimate ^{149}Sm creation
  - Requires fuel inventory data
  - Errors in assumed power division
- Future Work: replace tool



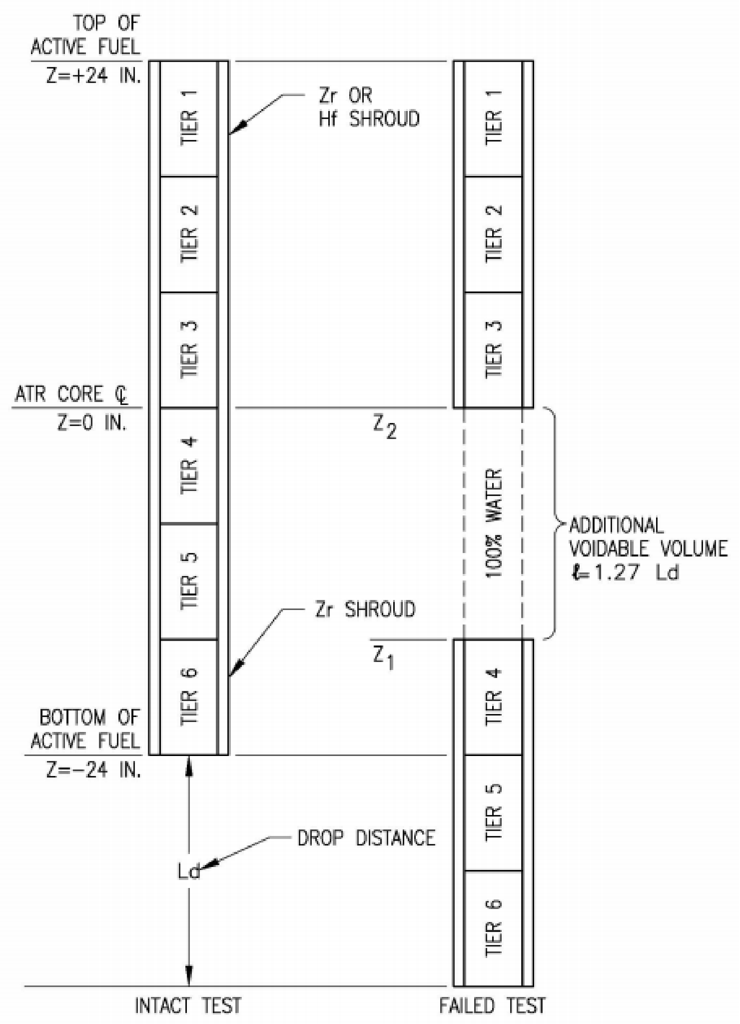
Power Divisions – Safety Rod Worths

- Old Process:
  - FU → FI → RHODOL → SUPRMAX
- Little difference in 3 test cases:
  - Old "FU" database
  - Newer "atrfuel" database
  - ^{149}Sm assumptions w/o RHODOL
- Compiled SUPRMAX for use on Windows machines
- Still want to replace SUPRMAX



Power Divisions – Experiment Failure and Voiding

- Old Process:
  - FU → FI → RHODOL → SUPRMAX → MAXVOID
  - Tightly coupled; most changes had downstream impact
- First improvement: decoupling
  - Bounding void analysis
  - > expected SUPRMAX powers
- Second improvement:
  - Compiled for Windows machines



Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

W W W . I N L . G O V