



SCALE Use at BWXT

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- Started with then B&W in January 1989, in reviewing old analyses, found cases which were KENO IV and KENO II.
- Notable items from those codes:
 - Fixed format input,
 - single array,
 - core card
- First reference of KENO use is 1973
- KENO IV referenced in 1981
- KENO V referenced in 1987



- SCALE 3 in 1989
- SCALE 4 in 1991
- SCALE PC in 1993
- SCALE 4.2 in 1995
- SCALE 4.3 in 1996
- SCALE 4.4 in 1999
- SCALE 5.0 in 2005
- SCALE 6.1 in 2014



- SCALE 3 running on an IBM Mainframe
- KENO V run with Hansen-Roach 16 Group Stand Alone Cross Sections
- 1989 – IBM Mainframe requires JCL ☺

```
//LLWCVTAG JOB (000420-LLW-P-090,BX17),WETZEL,MSGCLASS=X,CLASS=Z,  
// MSGLEVEL=1  
//* DOD 99/99/99  
//F1 OUTPUT CLASS=*,DEST=R6,JESDS=ALL  
//KENO5 EXEC SCAKEN5,GOSIZE=1920K,TME=88,OUT='*.F1'  
//GO.SYSIN DD *  
=KENO5  
...
```

- One dimensional calculations were run with ANISN



- Low priority on the IBM
- Most cases would only be run at night.
- A lot of hand checking of inputs before submitting
- Plotting was a character plot

Early Days of My Career



- *****
*****XXXXXXXX*****
*****XUUUUUUUX*****
*****XUUUUUUUX*****
*****XUUUUUUUX*****
*****XUUUUUUUX*****
*****XUUUUUUUX*****
*****XUUUUUUUX*****
*****XXXXXXXX*****
- *****



- A PC version became available around 1993
- Jezebel with $npg=300$, $gen=103$, and $nsk=3$ ran for 20 minutes, but it was better than waiting to the next day
- A moderated case could take most of a day

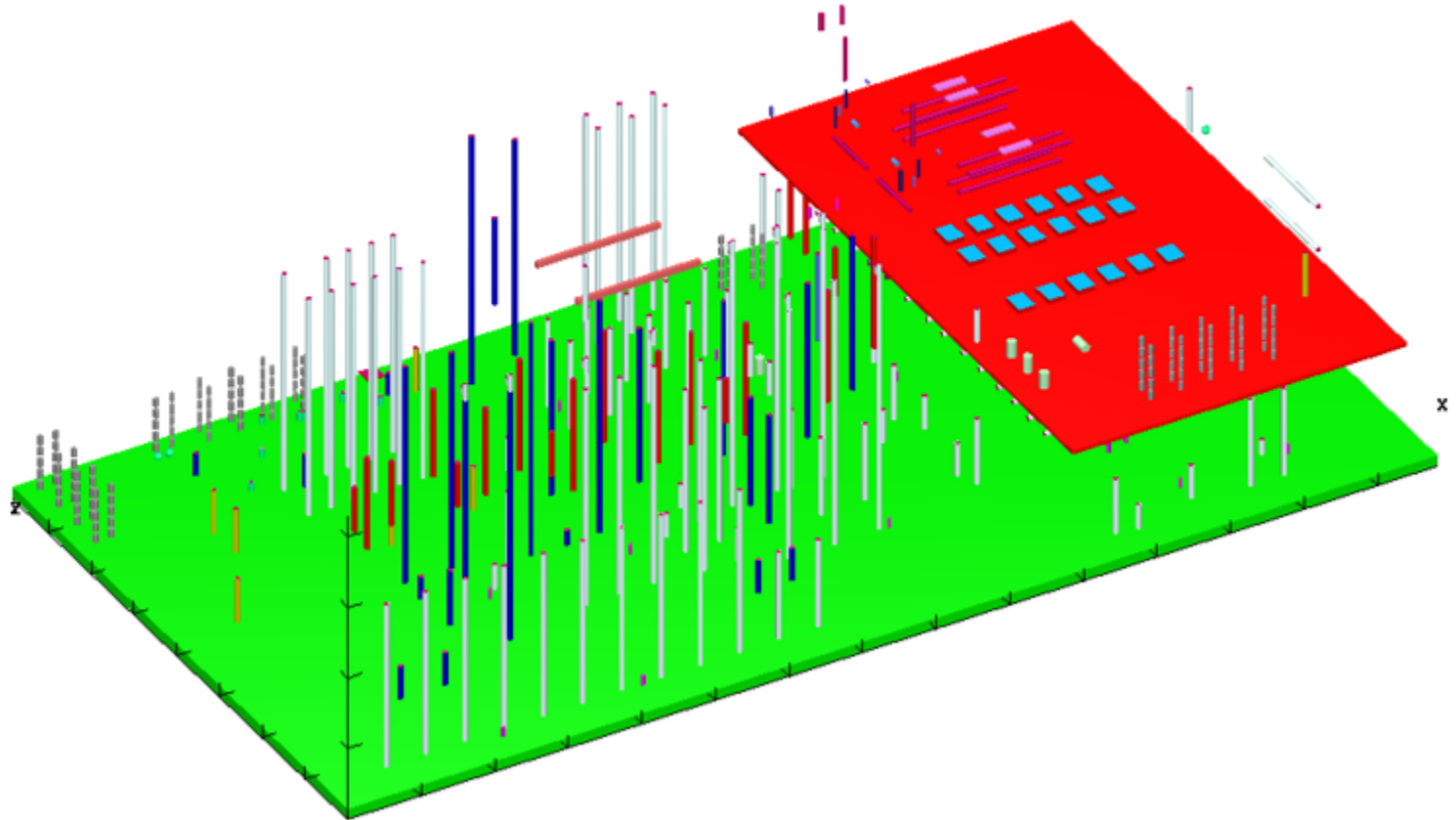


- Primarily we use CSAS5 to run k_{eff} calculations
- Most analyses are performed for a single unit with mirror boundaries on the lateral faces (infinite planar array)
- A quite conservative approach
- Uranium Recovery facility was analyzed using Solid Angle
- In 1990, the limiting solid angle was reached and a new approach was needed
- For 20 foot tall, 5 inch diameter columns in an infinite array, the necessary spacing was larger than existed in the facility



- A KENO-V model was developed for the entire facility covered by the solid angle technique
- The run times were a day or more on the IBM mainframe
- Time for a road trip to ORNL to see what could be done
- The long run time was due to the modeling technique
 - The facility was a single cuboid
 - Every piece of equipment was put in as a hole
 - 270 holes
- The model was converted to an array with one or two holes in each array element

Uranium Recovery

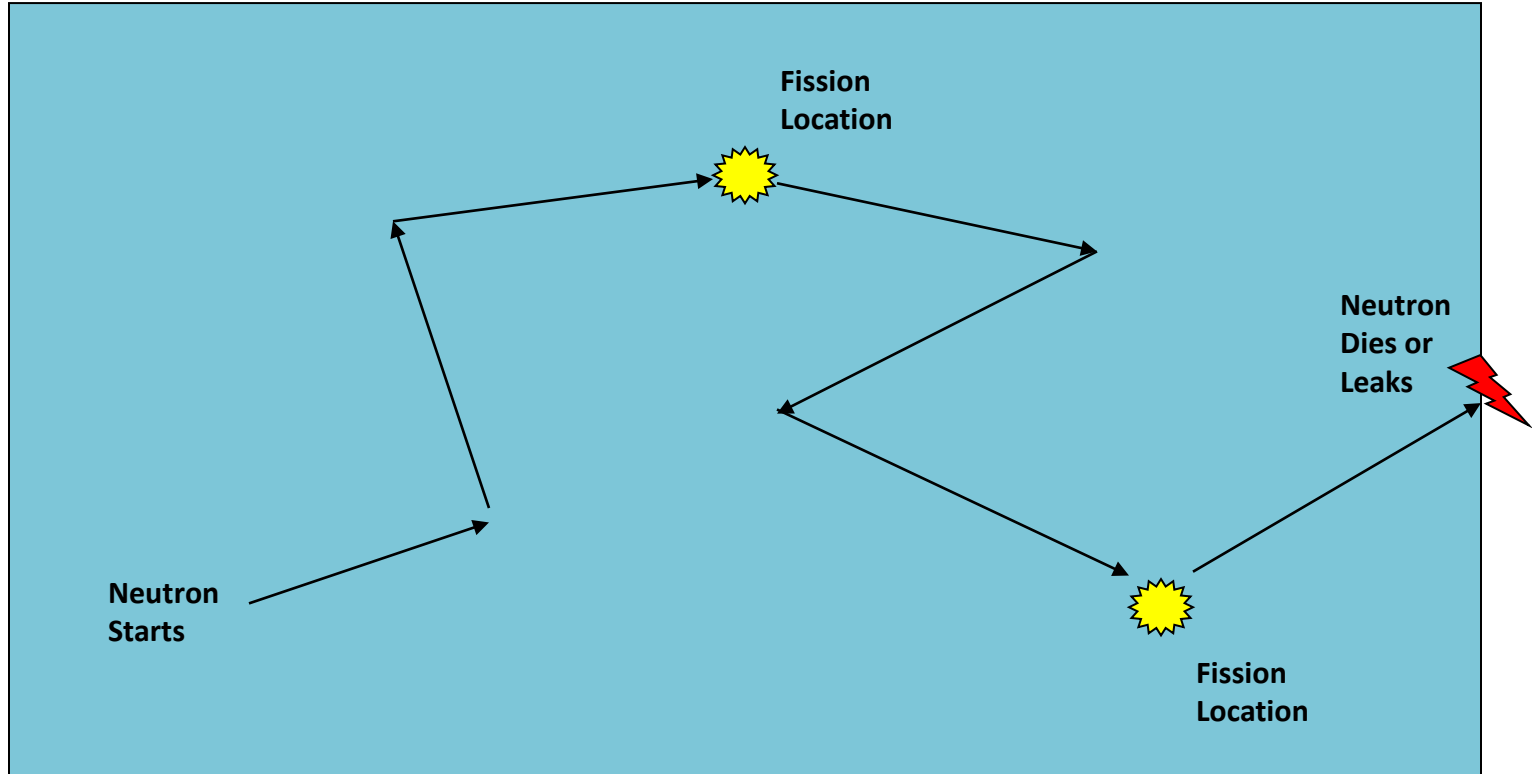




- The model used a start type 6 and had neutrons starting in every uranium containing unit
- A large number of generations were skipped to allow the source to converge.
- The output showed some locations with no fission, but there is uranium present
- WHY????

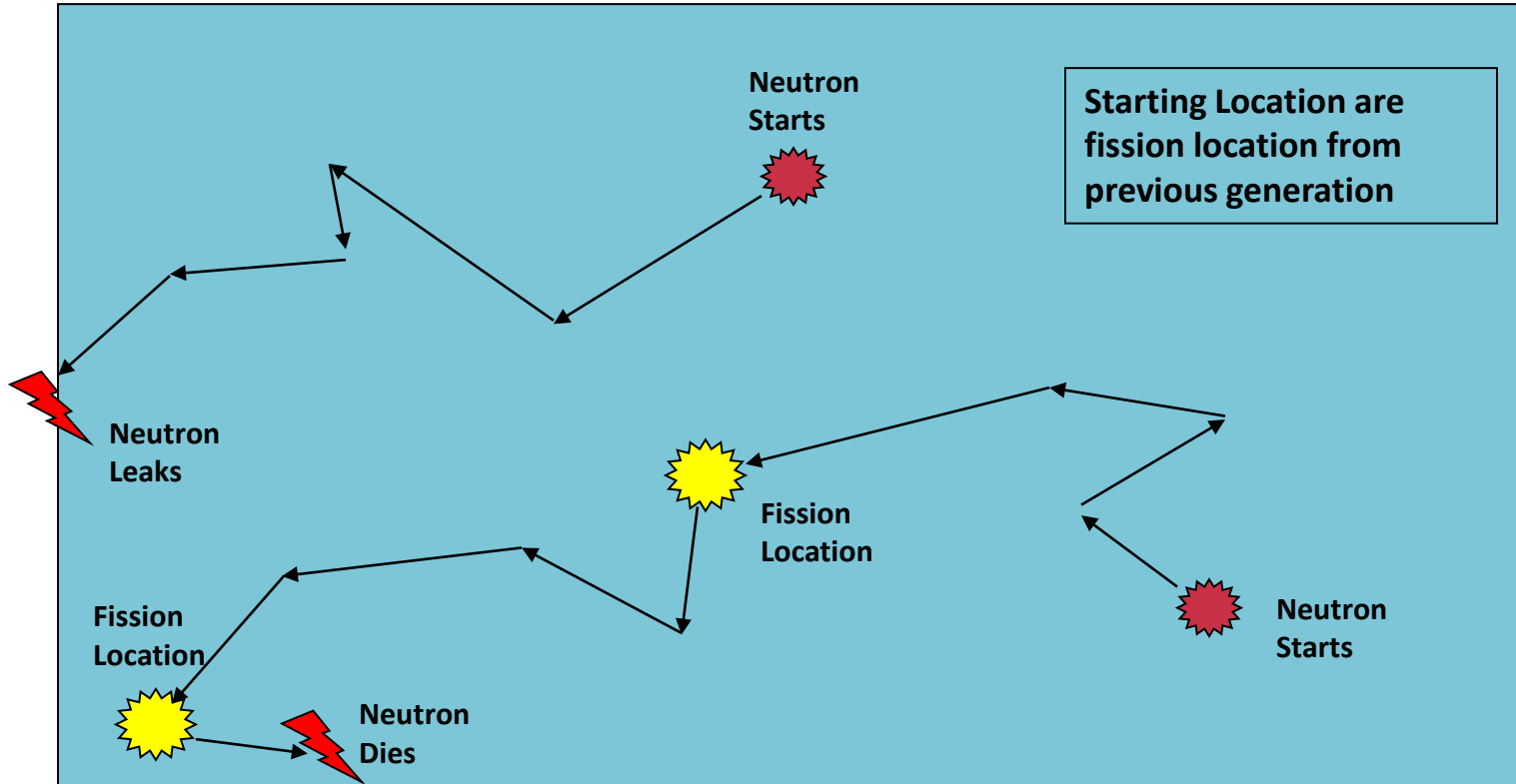


First Generation



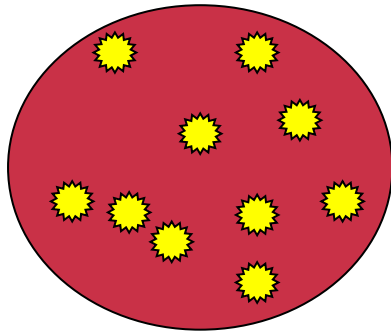


Second Generation

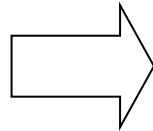
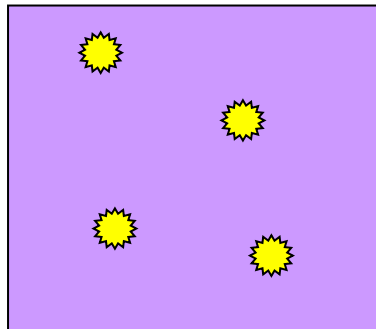




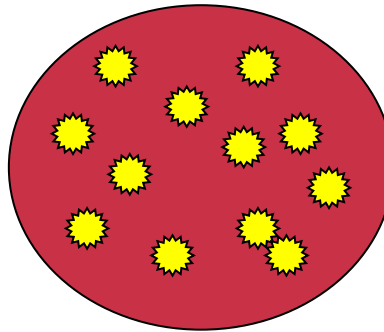
1st Generation
10 Neutrons Started



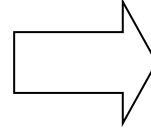
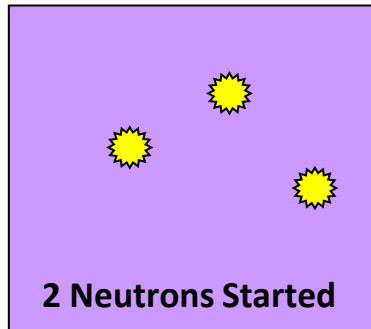
5 Neutrons Started in Each



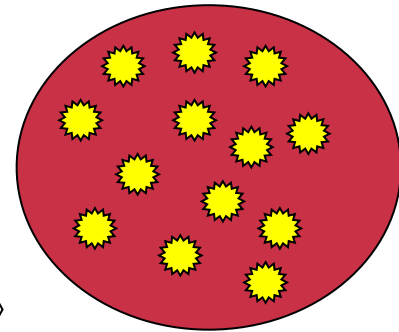
2nd Generation
10 Neutrons Started



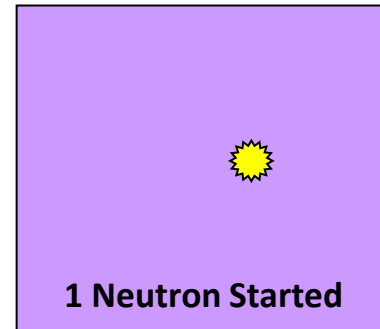
8 Neutrons Started



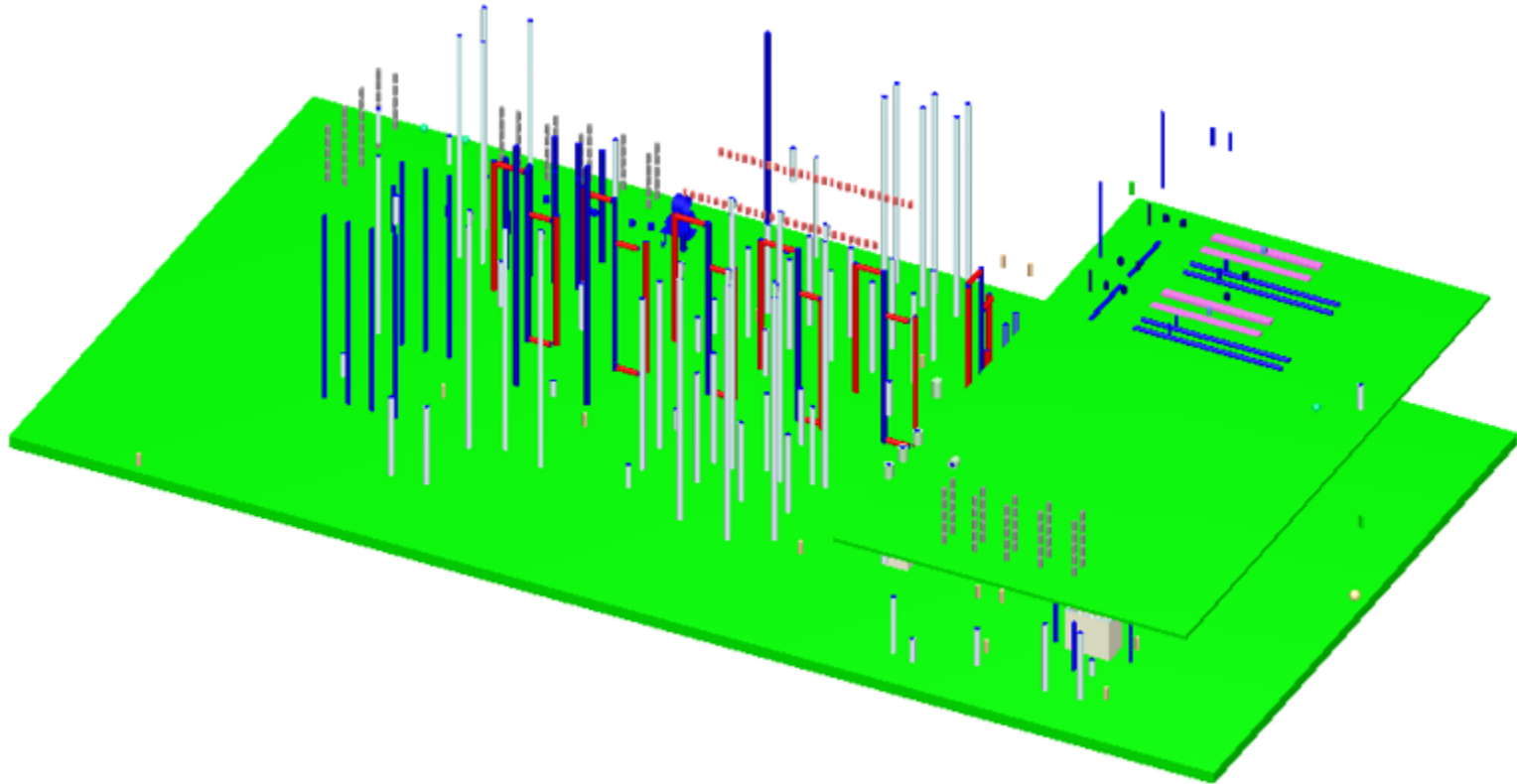
3rd Generation
10 Neutrons Started



9 Neutrons Started



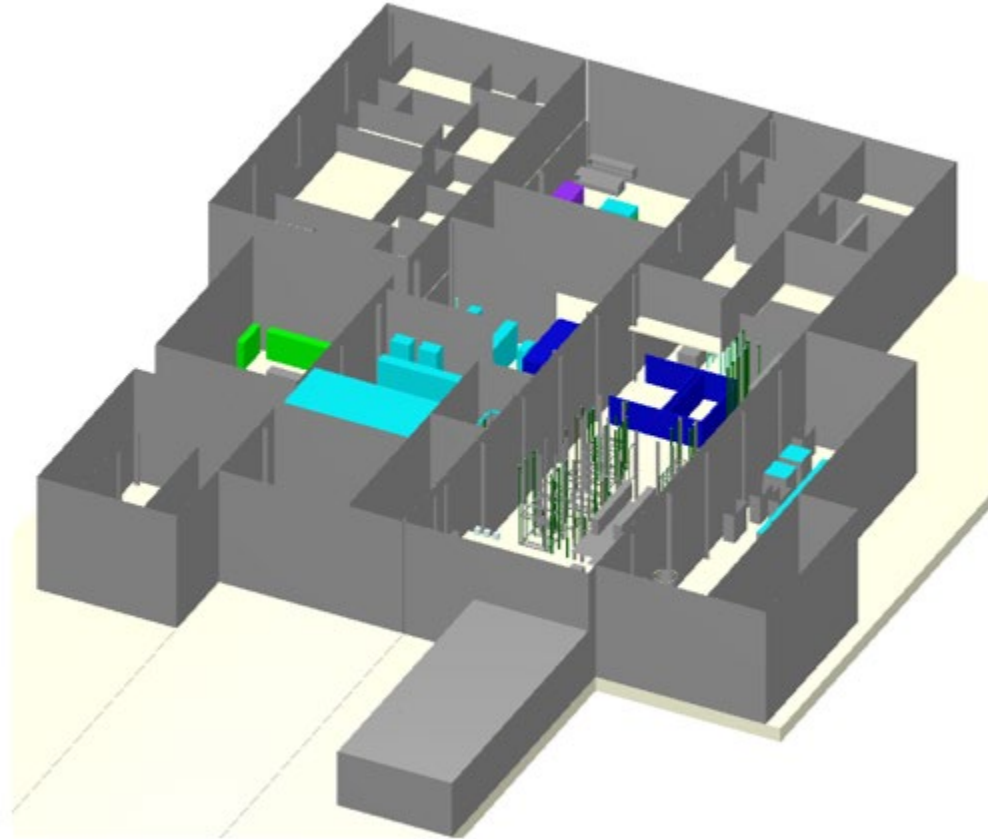
Uranium Recovery





- Around 2010, facility expansion required the installation of a new CAAS
- Previous detector placements were done using point kernel methods or in some highly shielded areas, MCNP
- MAVRIC was used to determine the detector placement in all buildings handling or storing uranium
- Due to the complexity of the problem, we contracted with ORNL and had Douglas Peplow spend a week at our facility helping develop the model
- His comment after touring our facility was “I am surprised you are getting any answers out of the code.” (It was a much bigger facility than he thought.)

A Section of the MAVRIC Model





- The code did work just fine, but the most common error was a geometry overlap. The issue is the size of the facility resulted in rounding errors.
- The model had thin wall, large equipment, and steel beams in each bay
- The bays were then combined to create the facility
- Run times per case were about 12 hours.
- Total cases were 302.
- In heavily shielded areas, FW CADIS was used. In most areas just straight analog.
- Douglas did write several utilities which help in post-processing the various output files.



- BWXT has been using KENO/SCALE for about 40 years at our facility. I have used them for 33 years.
- I have only used a small subset of the modules
 - MORSE
 - KENO-V and VI
 - NITAWL
 - XSDRN
 - CSAS (multiple versions)
 - TSUNAMI
 - MAVRIC



- What have I learned?
 - I have lot more to learn
 - I need to understand what the code does
 - I need to know what the answer should be
 - If it is not what I expect, dig into it