PennState
College of Engineering

NucE 497: Reactor Fuel Performance

Lecture 39: Final lecture

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Today we will discuss exam 2, look at results from the final project, and conclude the course

- Module 1: Fuel basics
- Module 2: Heat transport
- Module 3: Mechanical behavior
- Module 4: Materials issues in the fuel
- Module 5: Materials issues in the cladding
- Module 6: Accidents, used fuel, and fuel cycle

First, lets review the course

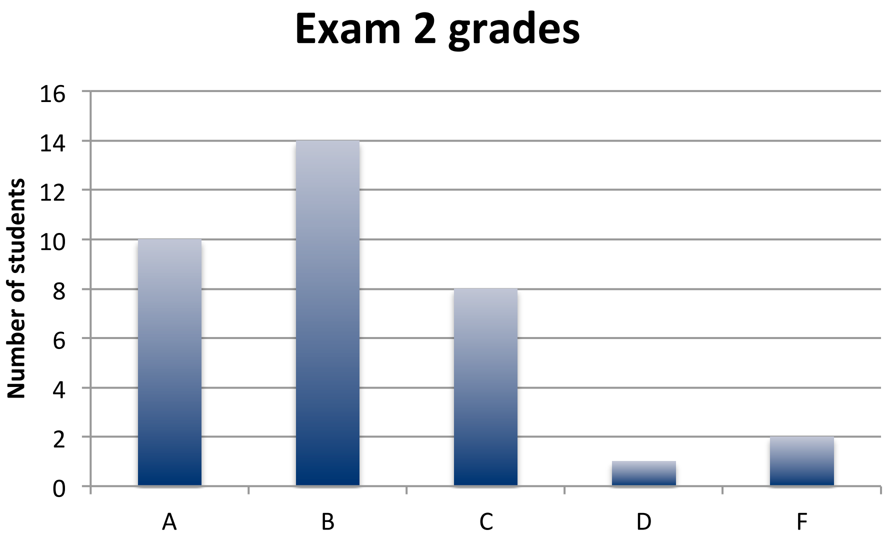
- I hope to use MATLAB again in
  a) About five minutes, I love it
  b) A week or two, it can be a pain, but it can be useful
  c) In about three months, summer is for playing not for MATLAB
  d) A thousand years or so
- Fuel performance is determined by
  a) Efficiency with which heat is transported to the coolant
  b) Reactor operating time
  c) Coping time in the case of an accident
  d) How good the reactor looks on TV

Remember to do the SRTE for this course

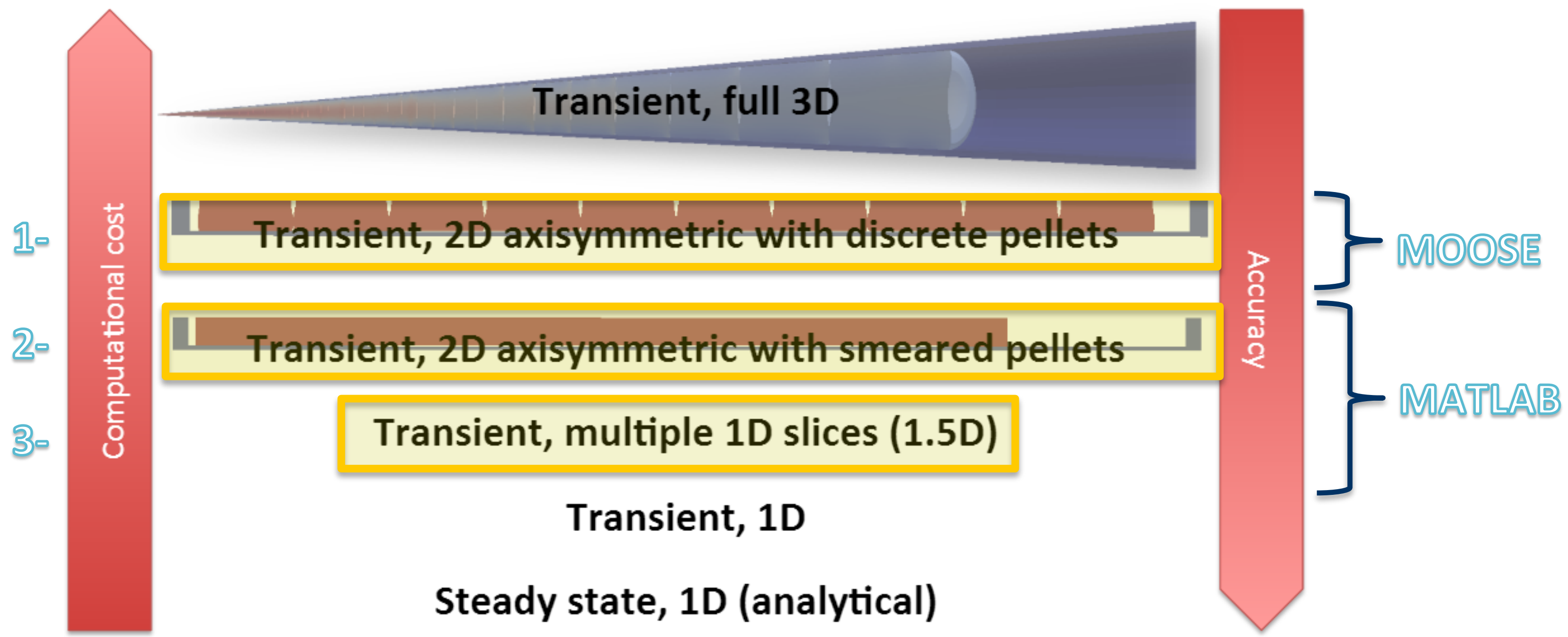
- You will earn extra credit on the final project
  - If 80% of you complete it, you will get +1%
  - If 90% of you complete it, you will get +2%
  - If 95% of you complete it, you will get +3%

The scores on Exam 2 on average were better than Exam 1

- The average score was 82% with a standard deviation of 14%
    - Problem 1: $\mu = 80\%$
    - Problem 2: $\mu = 77\%$
    - Problem 3: $\mu = 86\%$
    - Problem 4: $\mu = 82\%$



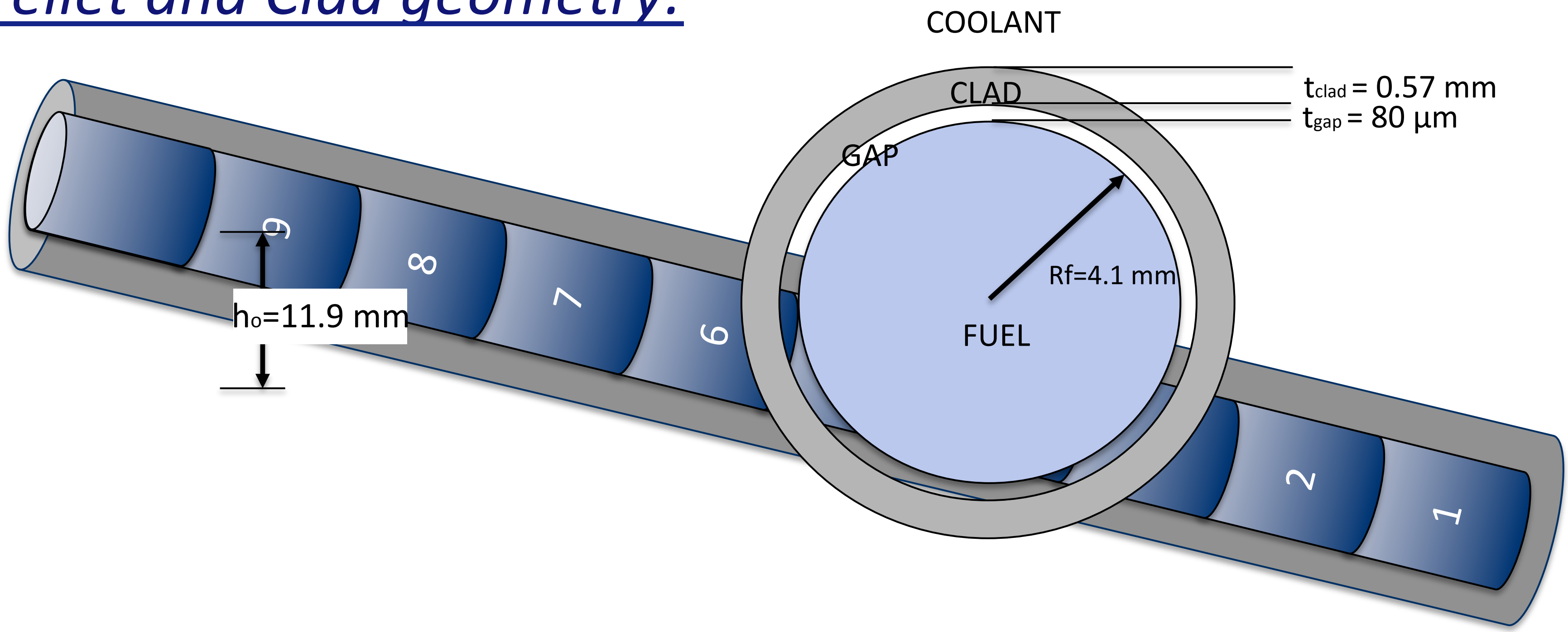
The goal of the project was to create and use a simple fuel performance code



You had the option to create a 1.5D code, a 2D RZ code with smeared pellets, or a 2D RZ code with discrete pellets.

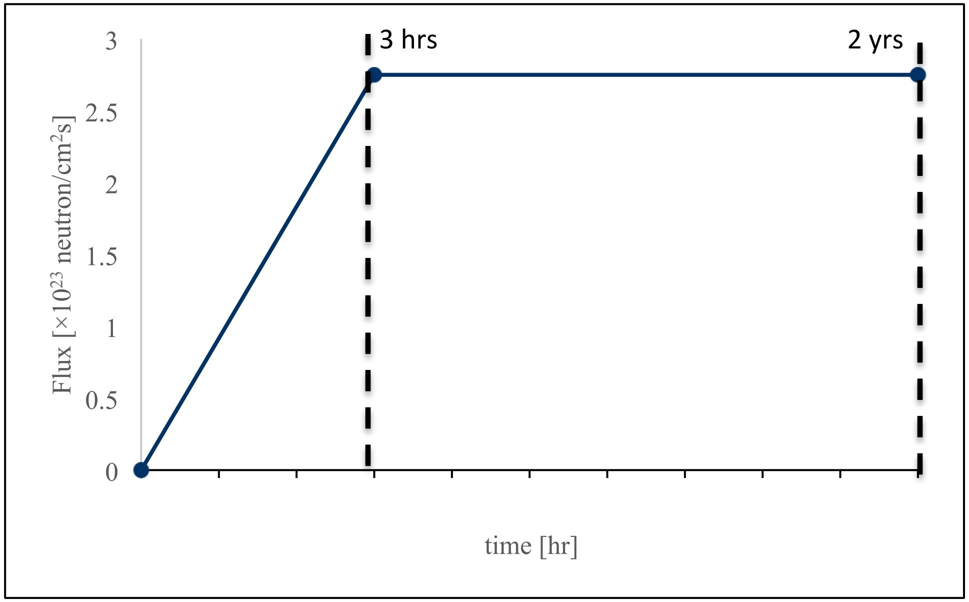
You modeled a fuel rodlet with ten UO_2 pellets and surrounded by a zircaloy cladding:

Pellet and Clad geometry:



Here is the general description of the project operating conditions:

- The power will linearly increase for 3 hrs before reaching its maximum value, resulting from a fission rate of $2.75{\times}10^{13}$ neutron/cm^{2}s. Power will hold there for 2 years.



The linear heat rate will vary axially according to the equation:

$$LHR\left(\frac{z}{Z_o}\right) = LHR^o \cos\left[\frac{\pi}{2\gamma}\left(\frac{z}{Z_o}-1\right)\right] = LHR^o\, F\left(\frac{z}{Z_o}\right)$$

Where

- LHR^0 is the centerline linear heat rate (z = Z0)
- $\gamma = (Z_{ex}+Z_o)/Z_o$ where Z_{ex} is the extrapolation distance
- $\gamma \approx 1.3$

Here is the general description of the project operating conditions (cont):

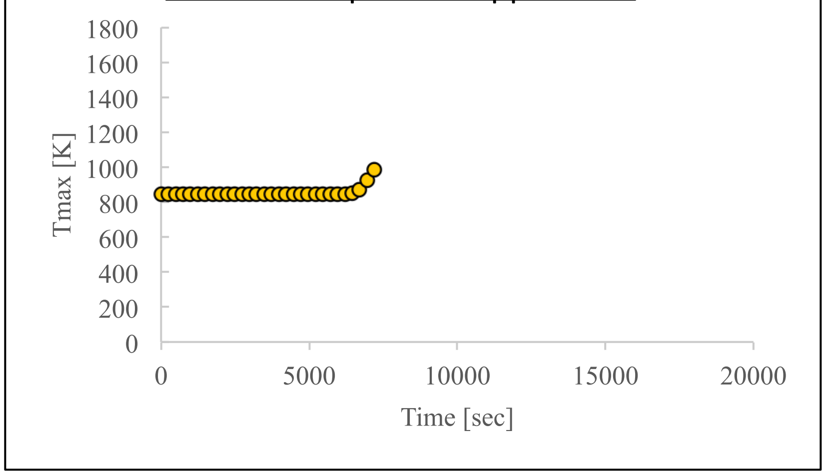
- $T_{cool,in}$ = 580 K,
- $\dot{m}$ = 0.25 kg/s
- C_{pw}= 4200 J/kgK

The coolant temperature along the length of the rodlet using the equation from slide 18 of lecture 7:

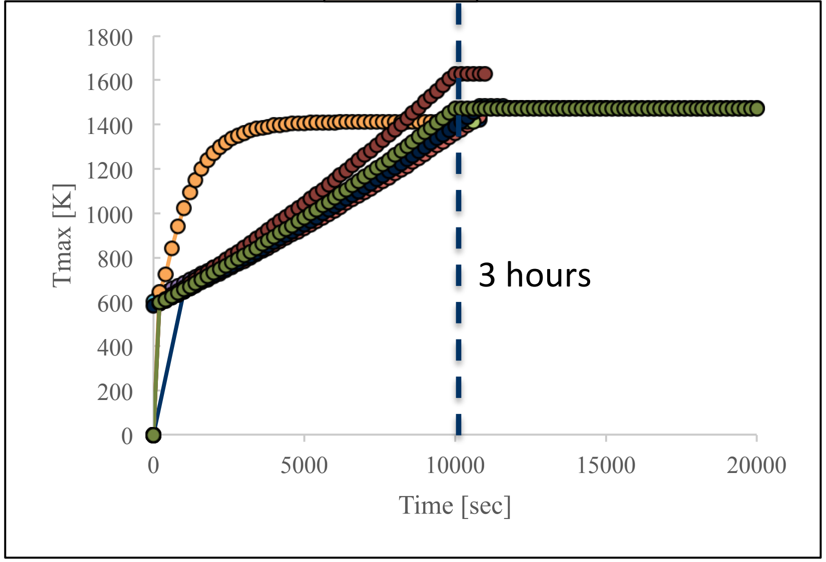
$$\boxed{T_{cool} - T_{cool}^{in} = \frac{2\gamma}{\pi}\frac{Z_0 LHR^0}{\dot{m}C_{pw}}\left(\sin\left(\frac{\pi}{2\gamma}\right) + \sin\left(\frac{\pi}{2\gamma}\left(\frac{z}{Z_0} - 1\right)\right)\right)}$$

Case 1: Burnup independent properties

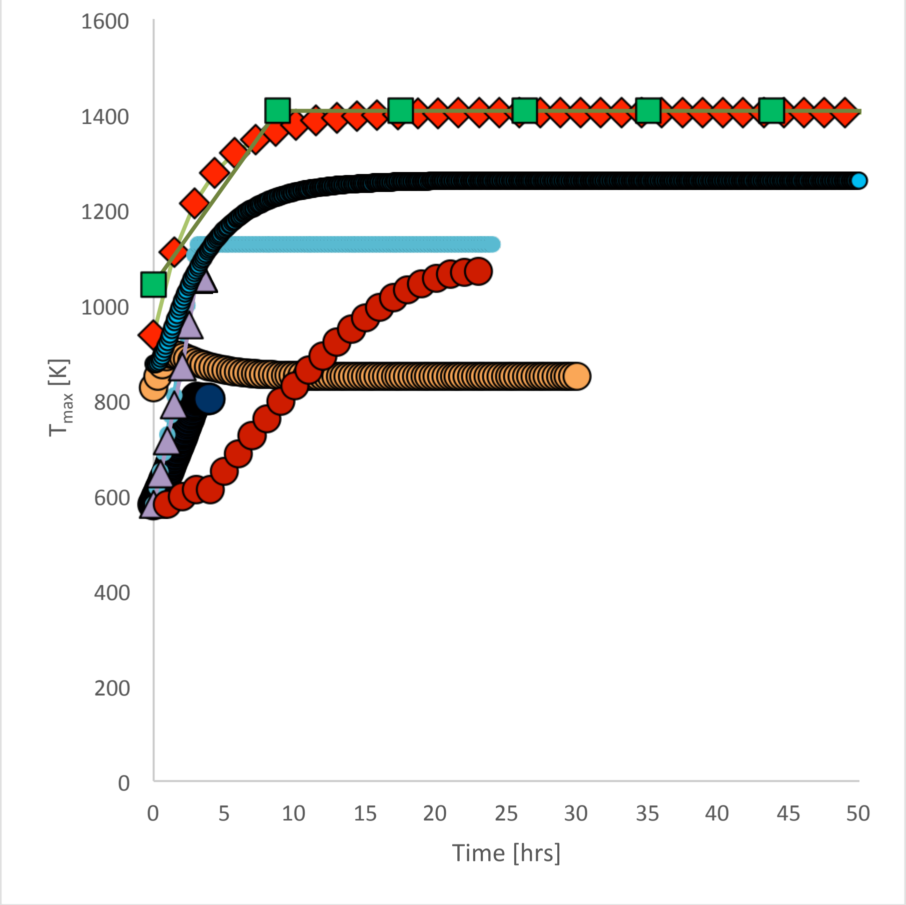
1.5-D multiple slice approach



MOOSE



2-D smeared approach



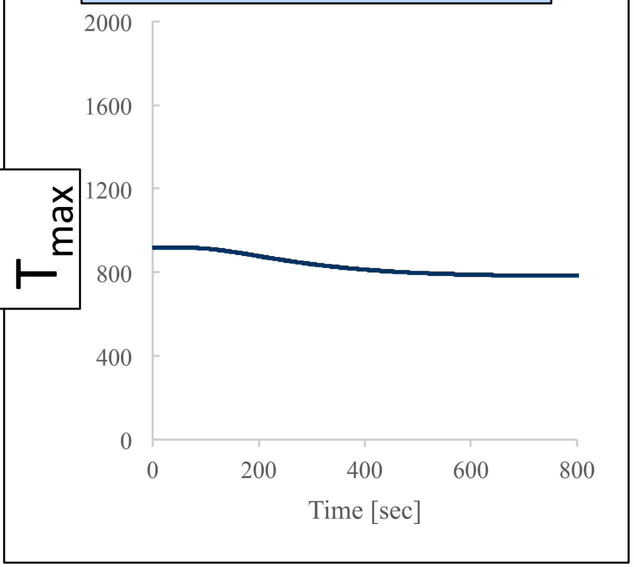
Case 2: Burnup dependent properties for two years

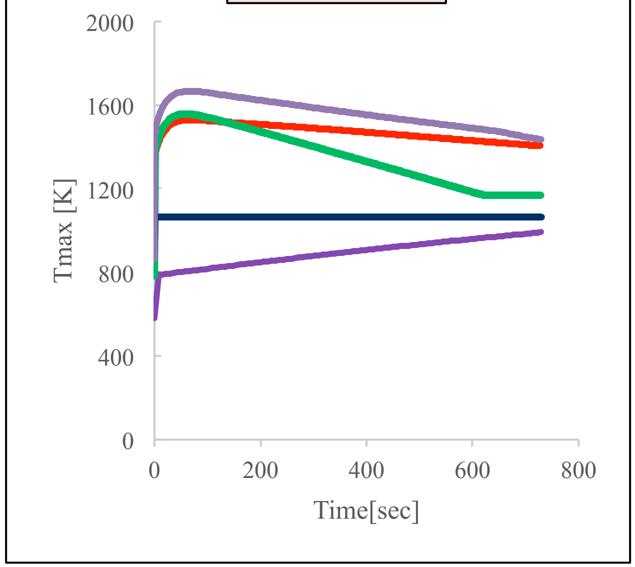
1.5-D multiple slice approach

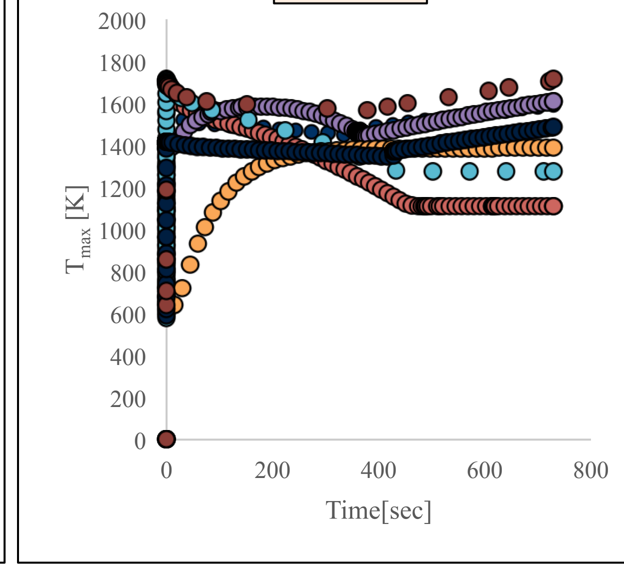
2D Smeared

MOOSE

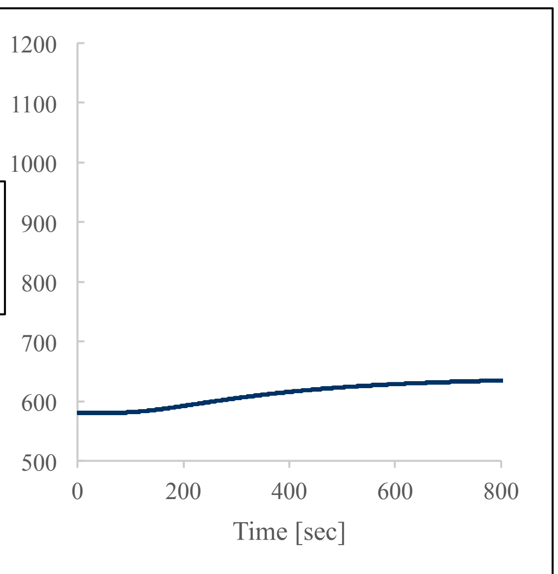
T_{max}

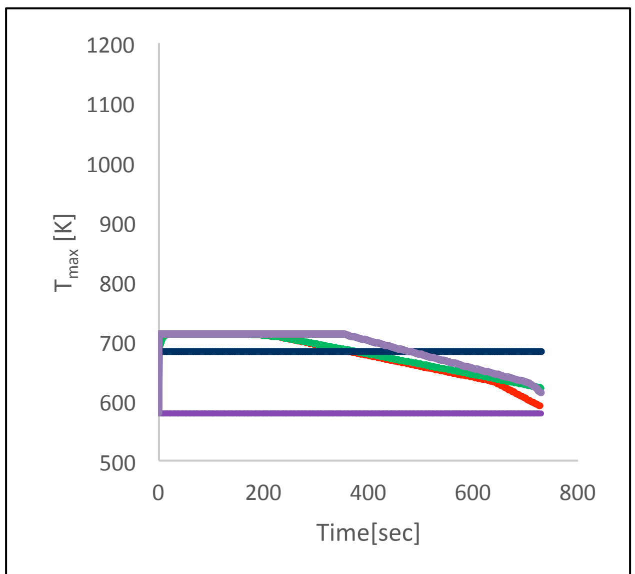


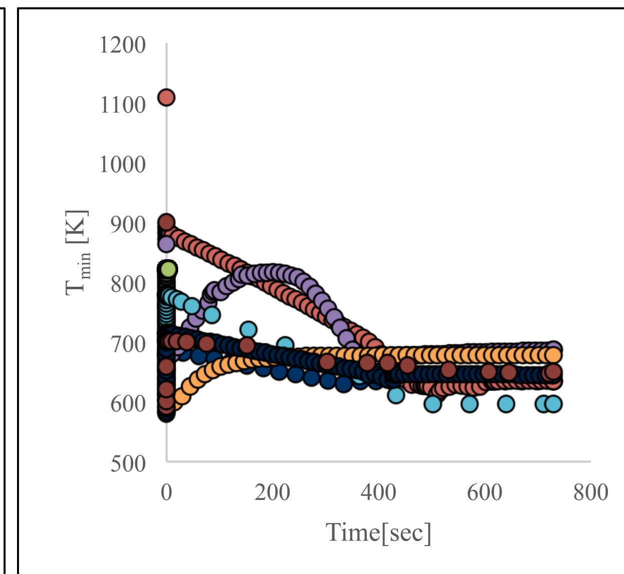




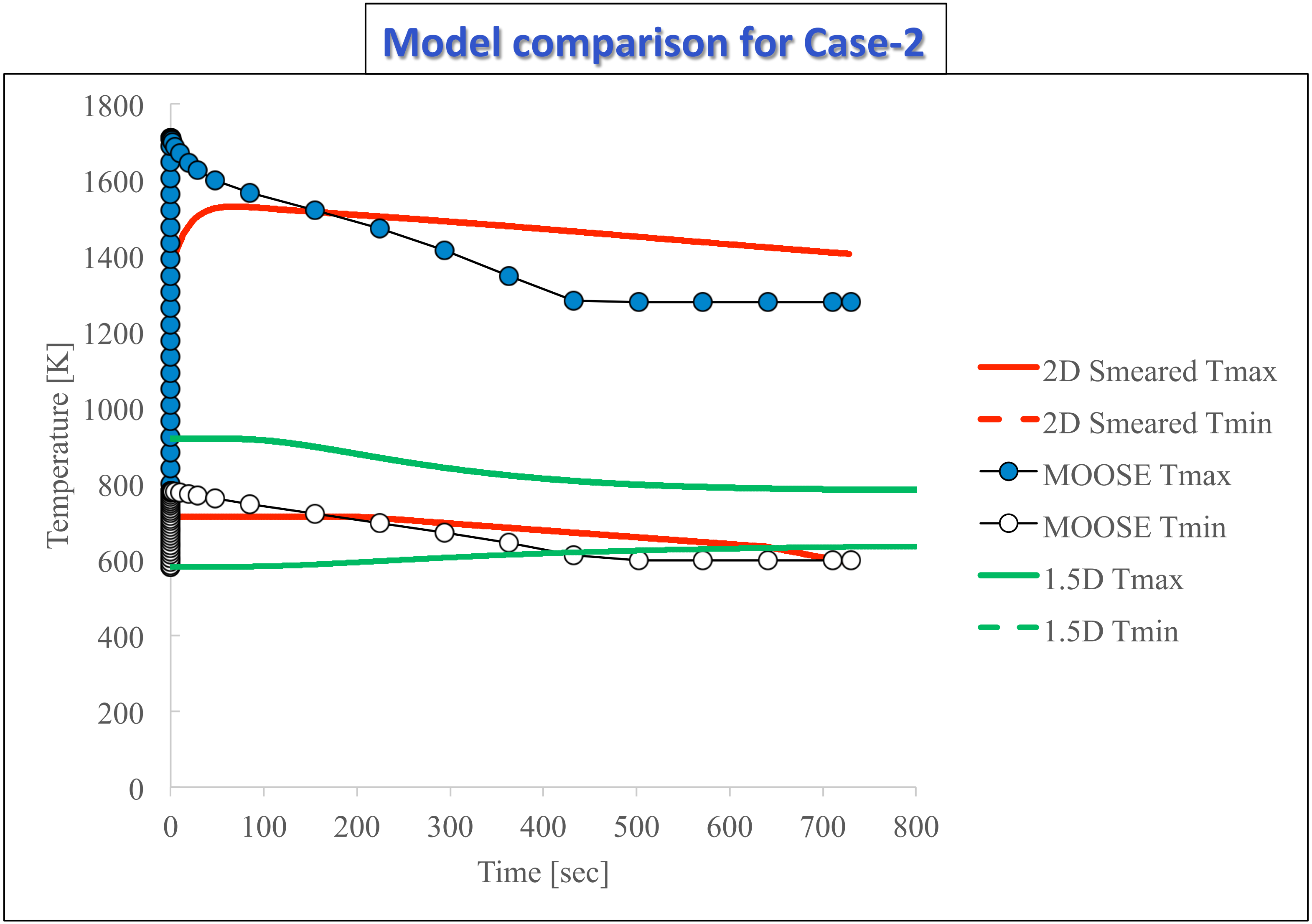
T_{min}





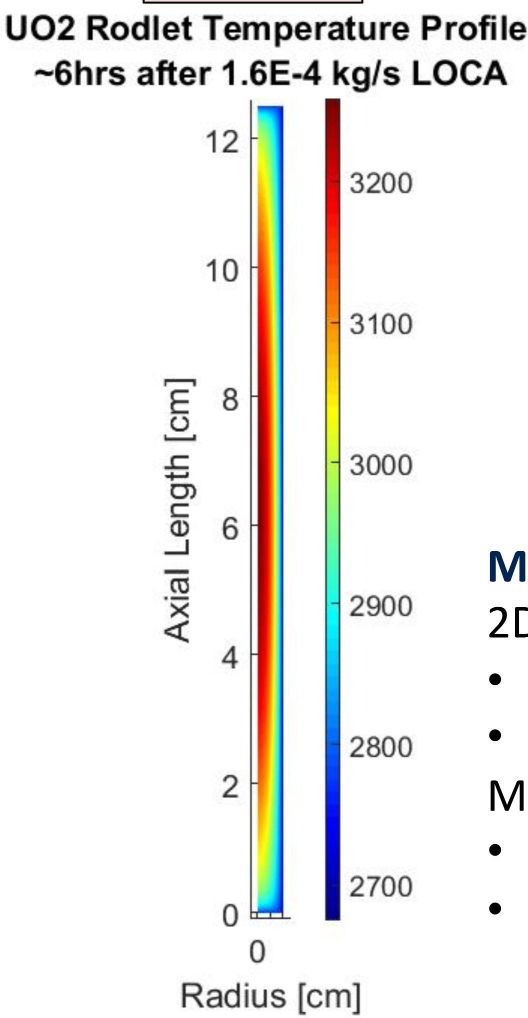


Case 2: Burnup dependent properties for two years

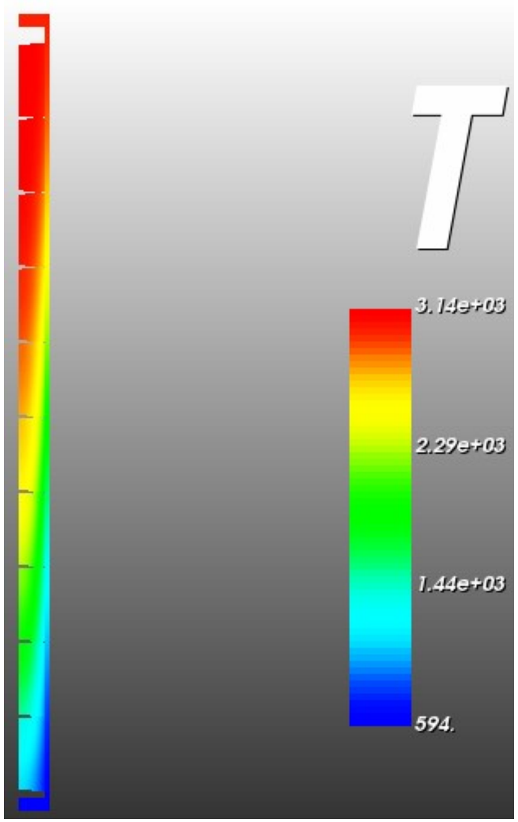


Case 3: LOCA and melting

2D Smeared



MOOSE



Melting flow rate:

2D smeared

- 1.6e-4 kg/s
- 2.5e-4 kg/s

MOOSE

- 2.2e-4 kg/s
- 2.7e-4 kg/s

Reactor fuel performance directly impacts reactor efficiency and safety

- The performance of the fuel is determined by
  - How efficiently it heats the coolant
  - Avoiding unplanned shutdowns (maximizing operating time)
  - Providing maximum coping time in an accident
- The primary quantities of interest are the
  - Fuel centerline temperature
  - Cladding stress

What impacts the fuel centerline temperature at the beginning of life?

What impacts the fuel centerline temperature after two years in a reactor?

What impacts the cladding temperature at the beginning of life?

What impacts the cladding stress after two years in a reactor?

Final life lesson: I'm used to school, but how do I know what to I do when I get a job?

- In school I have clear (or sometimes not so clear) assignments telling me what to do. What do you have in a job?
- In school, you have to turn in assignments by specific dates. What do you have in a job?
- In school, if I don't know how to do something, I go ask the professor. What should I do in a job?
- In school, there are rules I have to follow and if I don't, I get in trouble. Jobs also have rules, what happens if I don't follow them?