COMSOL v4.3 Workshop Introduction

presented by:

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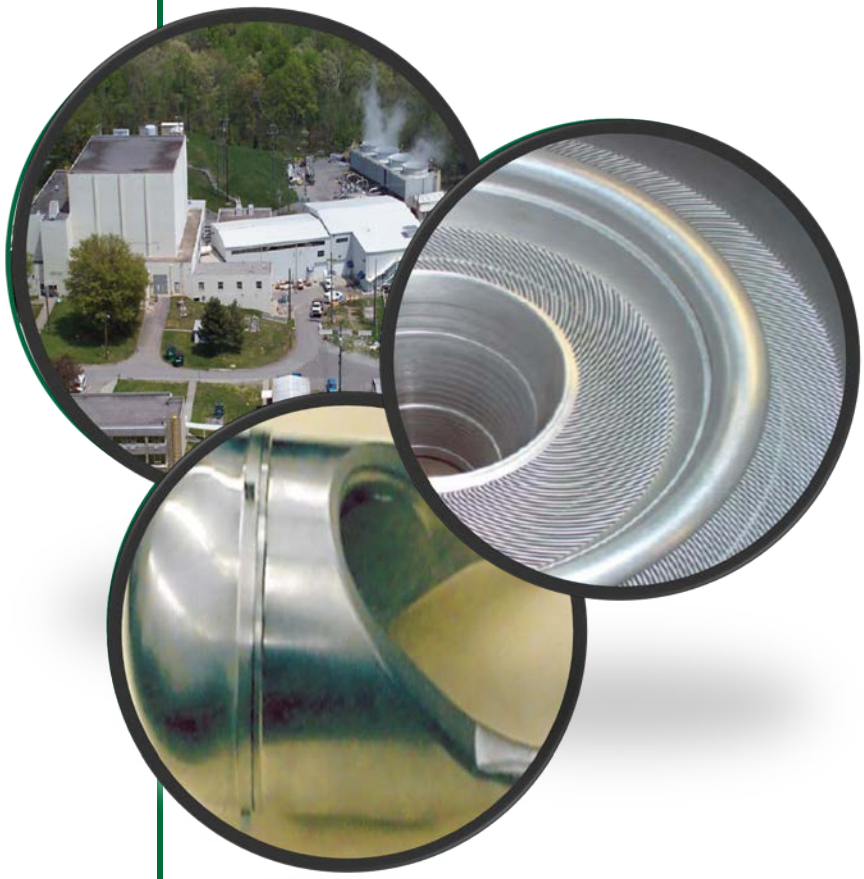
presented to:

Participants of the
COMSOL v4.3 Workshop
B 5200, Rm 202C, ORNL
Oak Ridge, Tennessee, USA

June 27, 2012



U.S. DEPARTMENT OF ENERGY

HFIR

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Welcome to the COMSOL v4.3 Workshop !

- *Jim Freels:* Brief History and Current Usage of COMSOL Multiphysics in Research Reactors Division (RRD)
- *Welcome Bjorn Sjodin:* COMSOL Multiphysics v4.3 Introduction, new capabilities, and conduct hands-on Workshop.

Introductory User Topics:

- multi-physics and why we have chosen COMSOL,
- past success of COMSOL applied to HFIR,
- new success of COMSOL on the production of Pu-238 in HFIR
- multi-physics applied to HFIR LEU conversion
- PDE/ODE mode applied to HFIR neutronics

My One-Sentence Description of COMSOL:

- A finite-element based computer simulation toolbox

COMSOL is our choice because: part 1 of 2

- Finite-element methods are (arguably from advocates of other methods) the most accurate numerical simulation tool available for deterministic solutions.

- COMSOL is a nearly100%-true finite-element method code for all the physics to be simulated by COMSOL (exception Particle Tracing Module).

- COMSOL is (arguably) the only true-multiphysics code commercially available (CFD, heat transfer, structural mechanics, PDE mode, etc. on our projects).

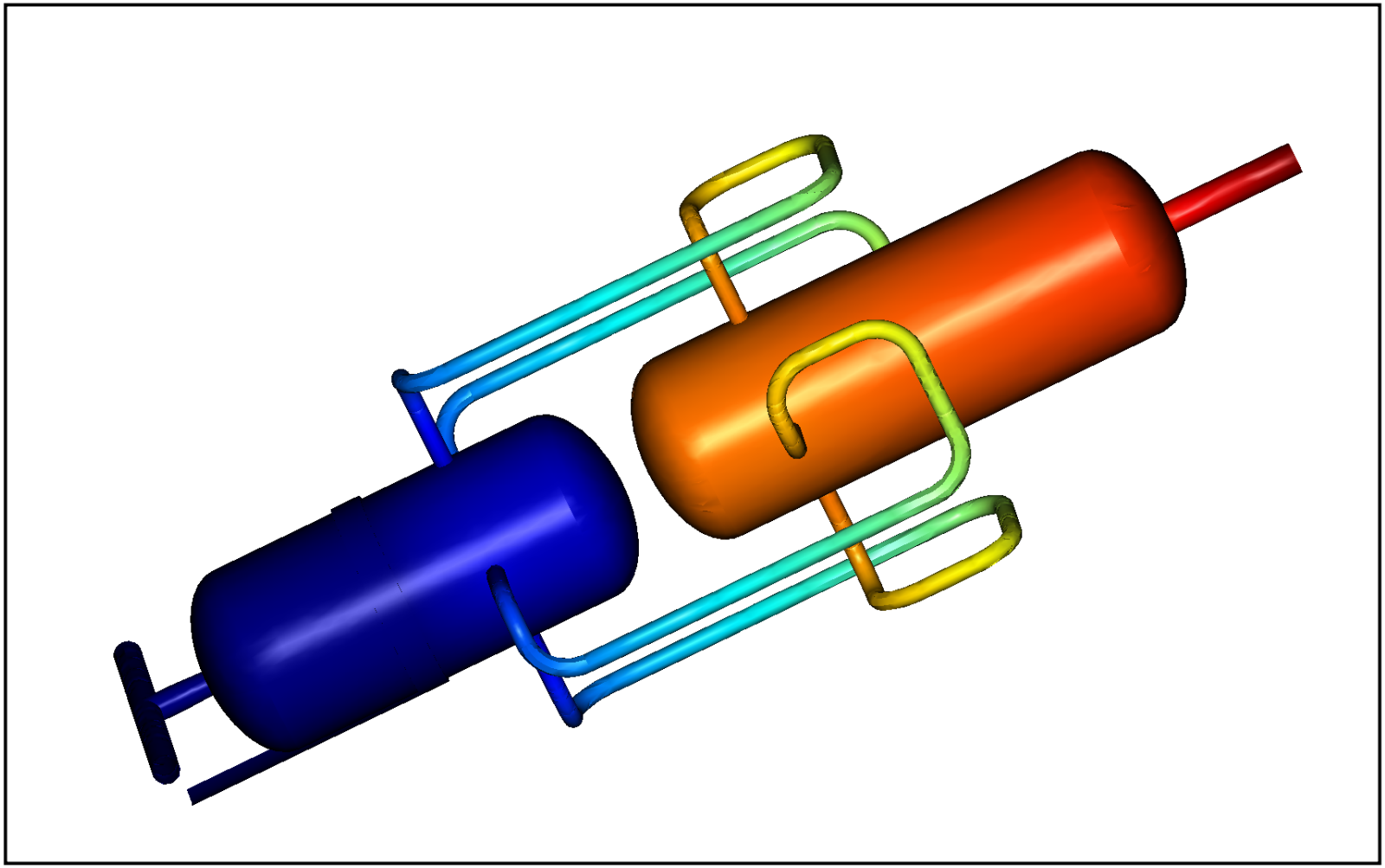
COMSOL is our choice because: part 2 of 2

- If desired, the standard equations solved may be altered on *INPUT* by the *USER* (for example, constituitive equations including turbulence model).
- You can solve your own equations from scratch (PDE, ODE, algebraic, functions, etc.)
- COMSOL provides a convenient GUI in modern computing environments.
- COMSOL continues to provide technical support and code improvements at a remarkable pace (distributed parallel processing, new modules, interface tools, response to user requests, etc.) now at v4.3 !

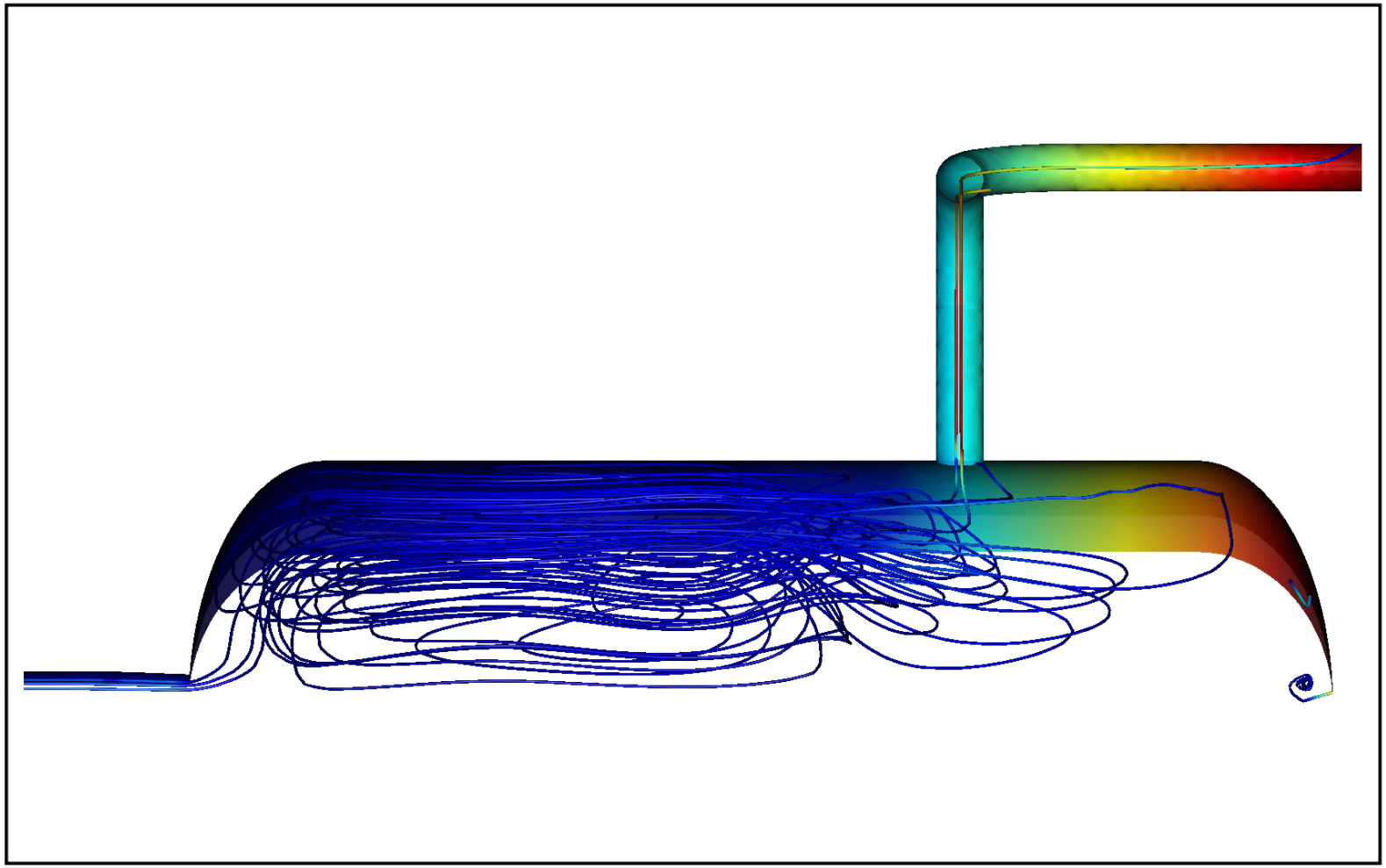
Success Story: COMSOL (FEMLAB)on the HFIR Cold Source Project

COMSOL was the design basis tool for the cold source pressurizer

Success Story: COMSOL multiphysics simulation of the HFIR cold source pressurizer Part 1 of 2



Success Story: COMSOL multiphysics simulation of the HFIR cold source pressurizer Part 2 of 2



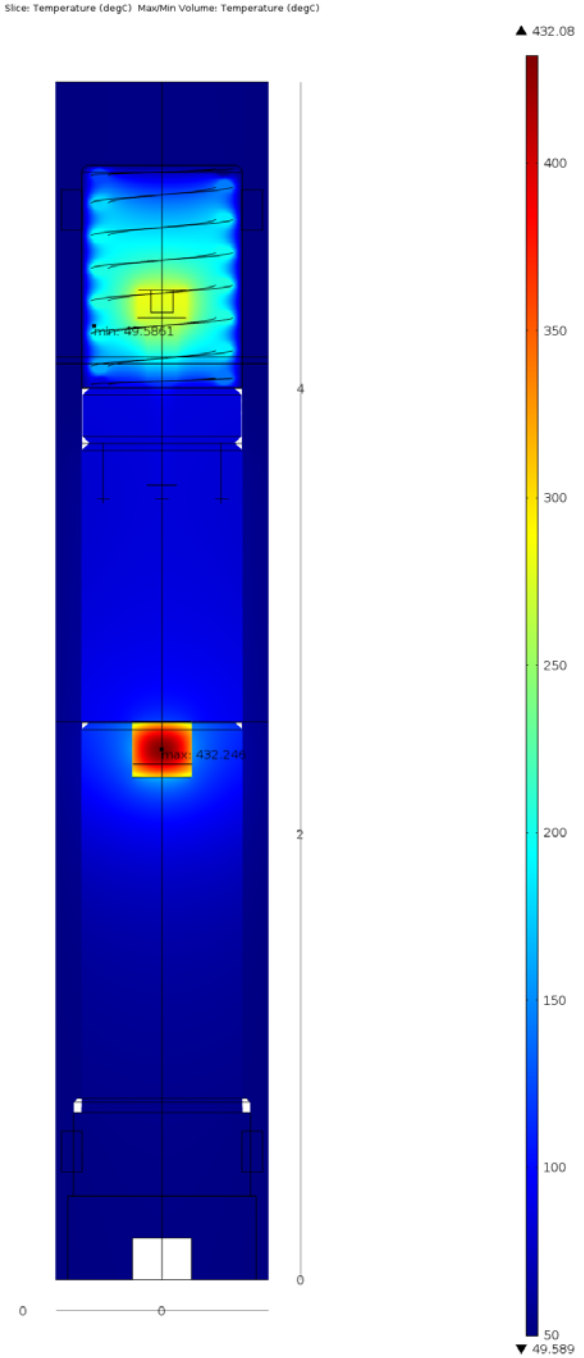
Next Success Story: COMSOL on the HFIR Pu-238 Project

V4.2a SQA approved

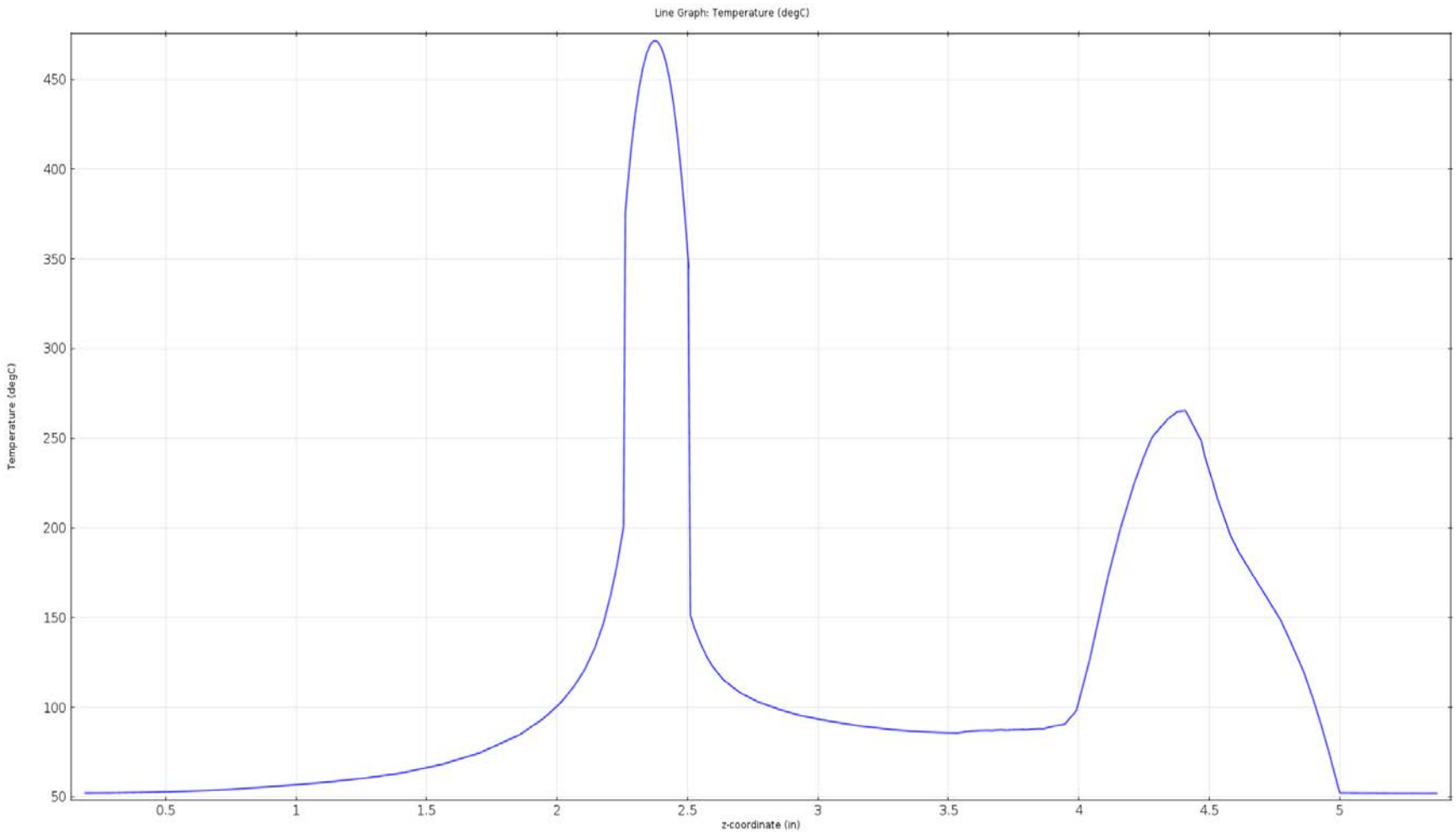
Preparer: James D. Freels
Check/Review: Prashant K Jain

Student Analyst in training:
Christopher J Hurt
PhD Student – UTK-NE

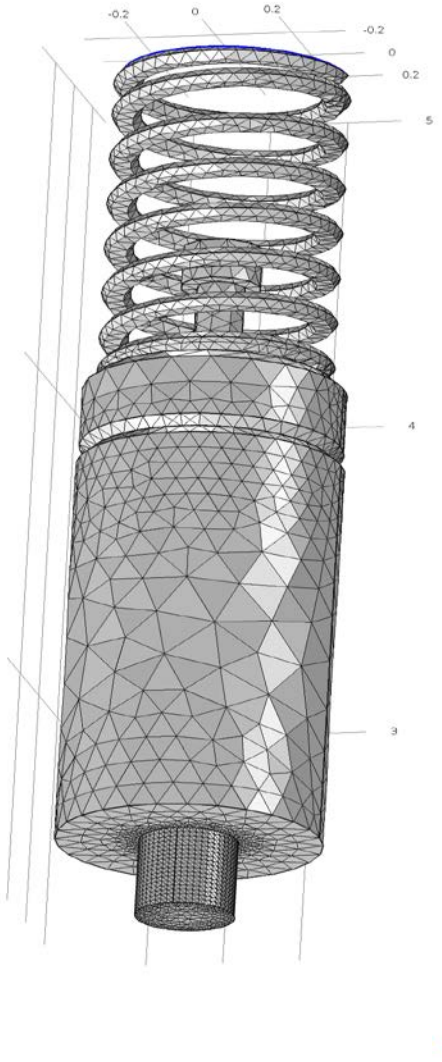
COMSOL is the design- and safety-basis tool for the Pu-238 bare-pellet capsule

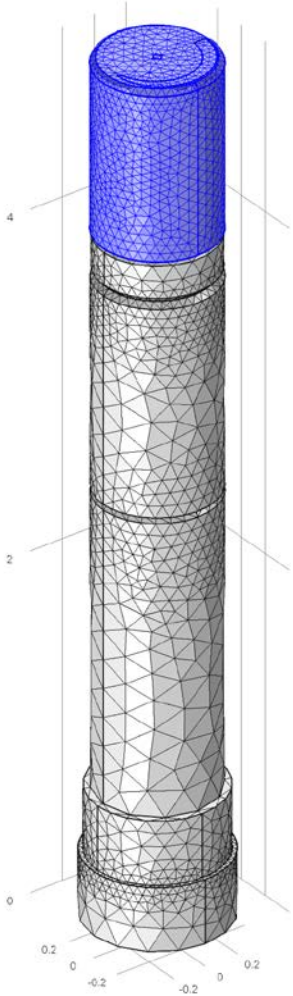


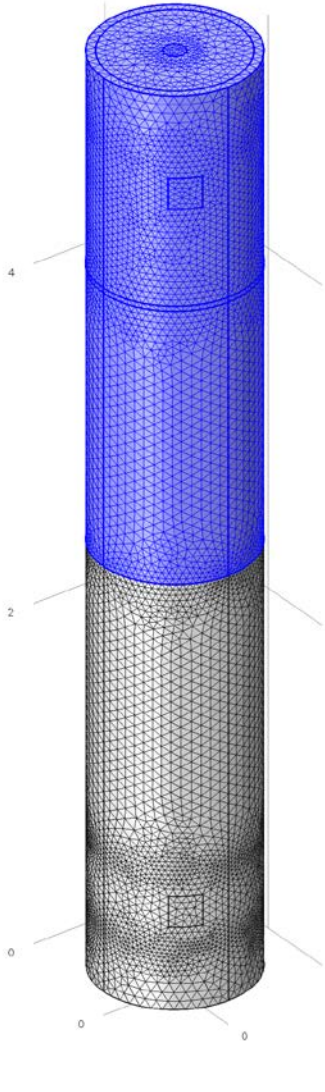
The Pu-238 bare-pellet capsule is expected to load into HFIR "next cycle"



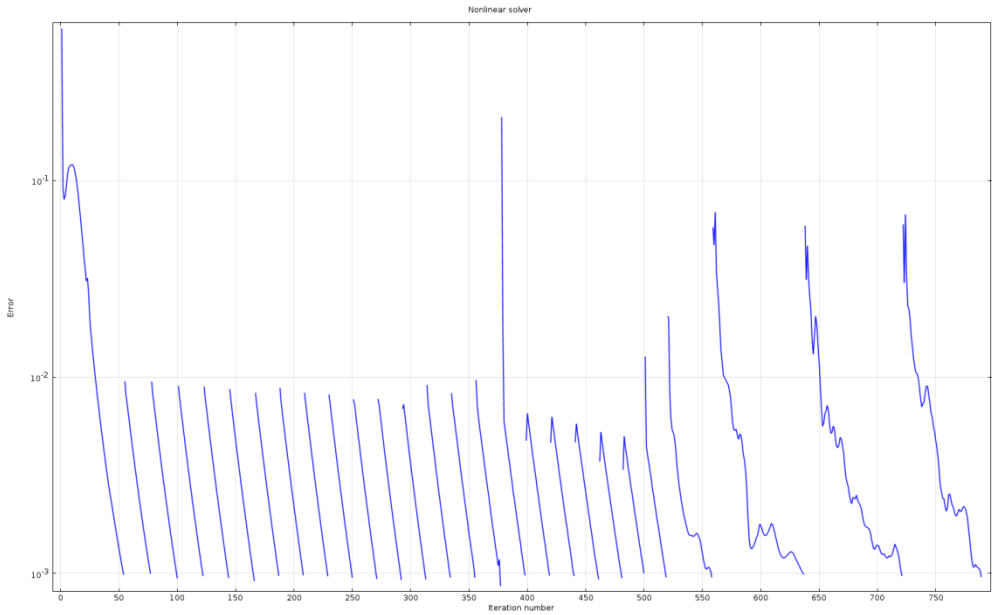
The Pu-238 bare-pellet capsule model utilizes CAD import for the geometry

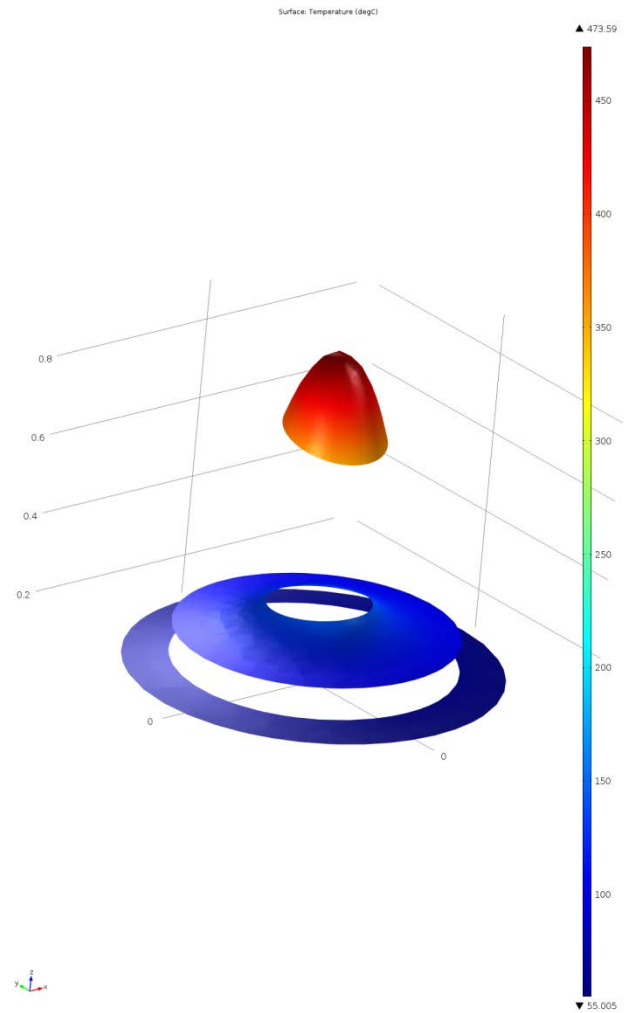






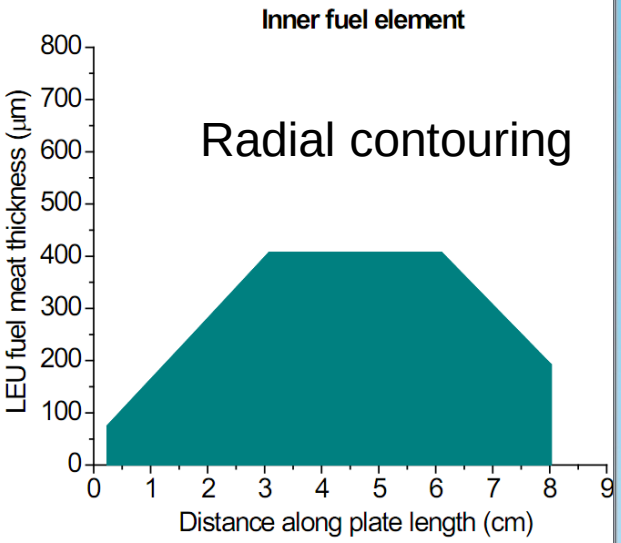
The Pu-238 bare-pellet capsule model Several Multiphysics Features



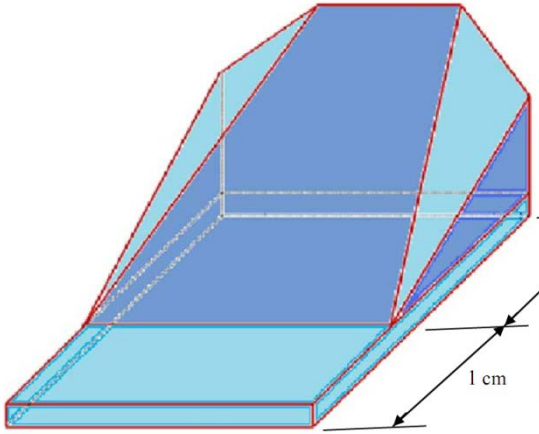


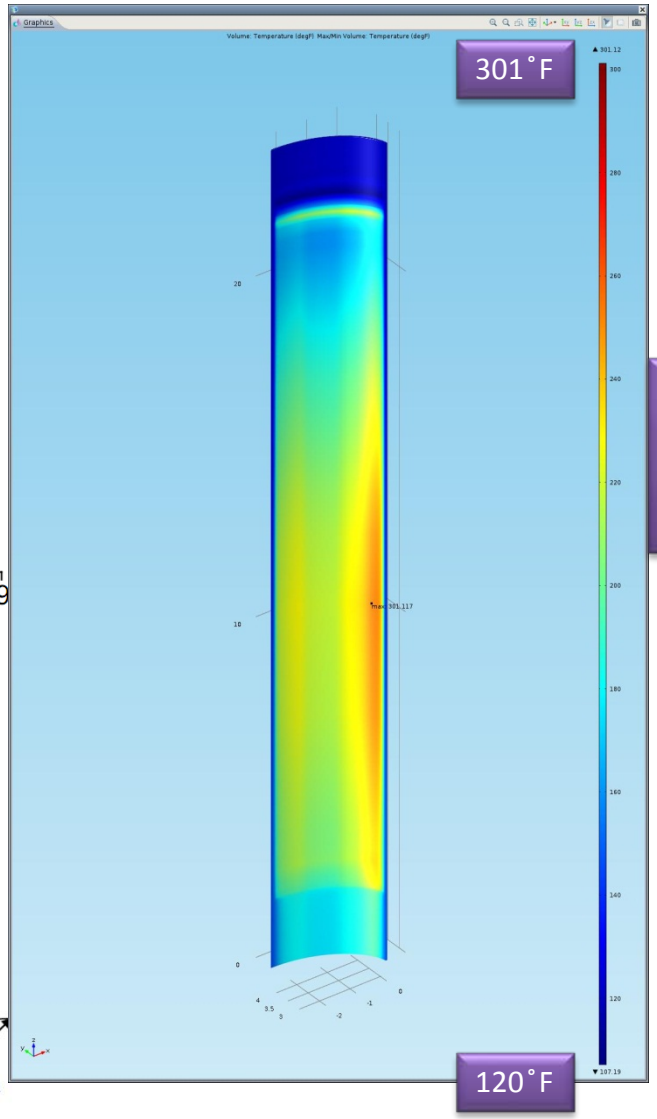
Convergence curves of parametric sweeps on power level. Higher power levels cause the pellet to receive forces from the side wall due to thermal expansion. Gas-gap conductance is simulated using the thin-film resistance feature of COMSOL.

COMSOL is Benefiting the HFIR LEU Conversion Project – fuel profile studies

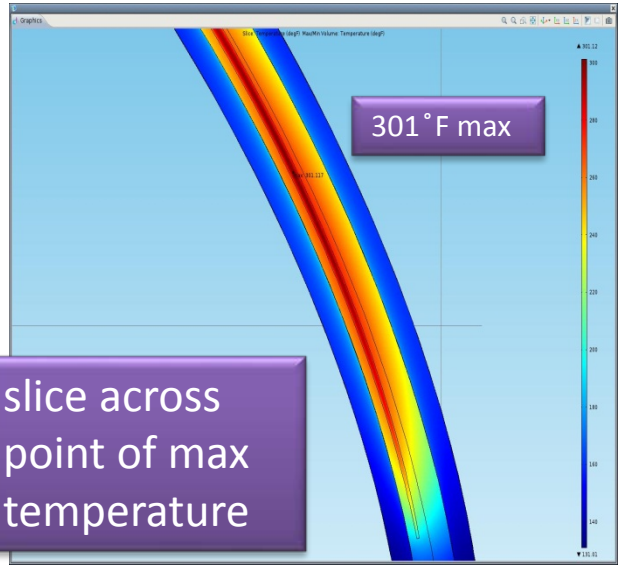


Axial contouring (bottom of fuel)

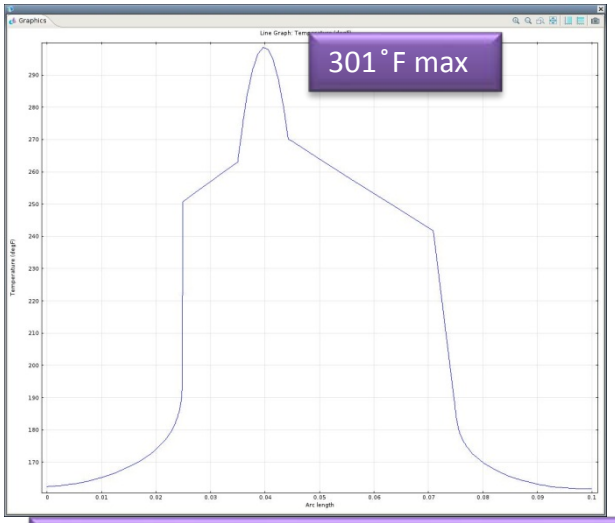




inner fuel plate surface temperature

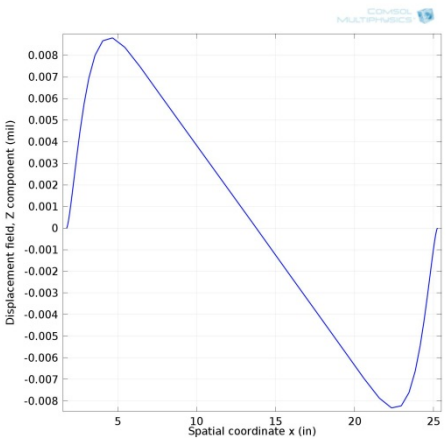


slice across point of max temperature

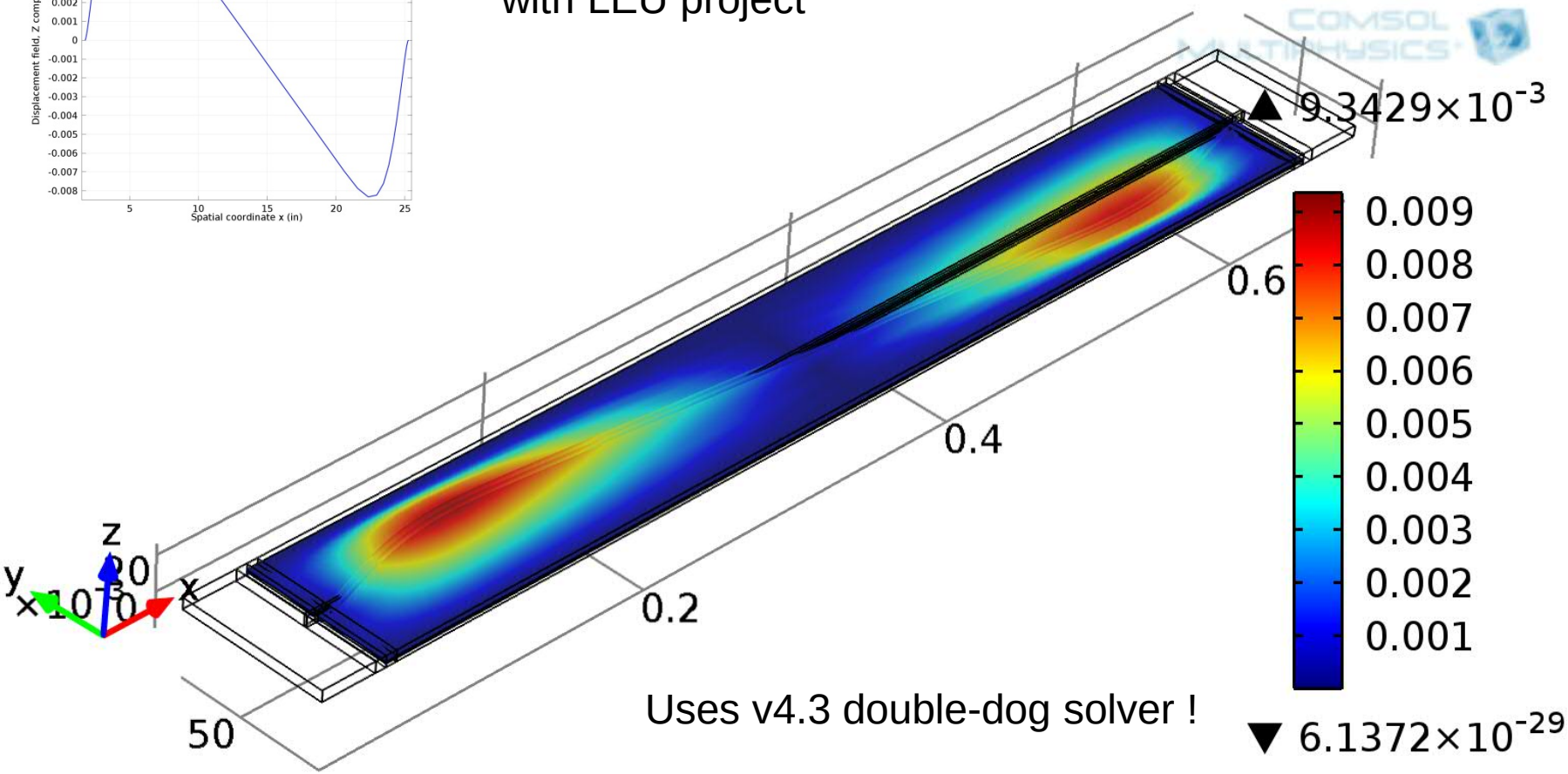


3D cut line at point of maximum temperature

COMSOL is Benefiting the HFIR LEU Conversion Project – fluid-structure interaction

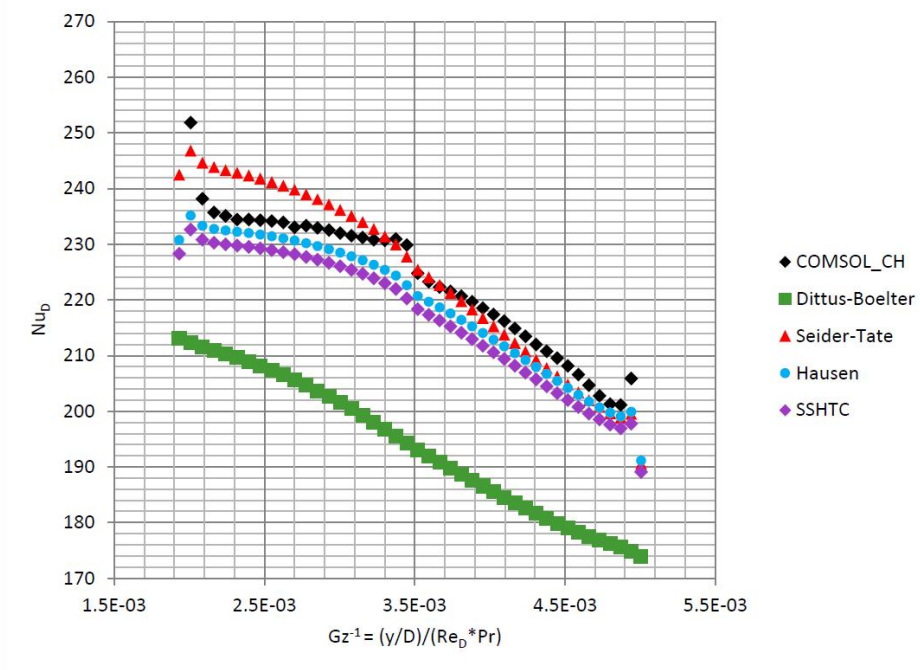


Research performed by
UTK-MABE PhD Candidate
Franklin C. Curtis on contract
with LEU project



Uses v4.3 double-dog solver !

COMSOL is Benefiting the HFIR LEU Conversion Project – conjugate-gradient heat transfer V&V



Research performed by UTK-MABE PhD Candidate Isaac T. Bodey on contract with LEU project.

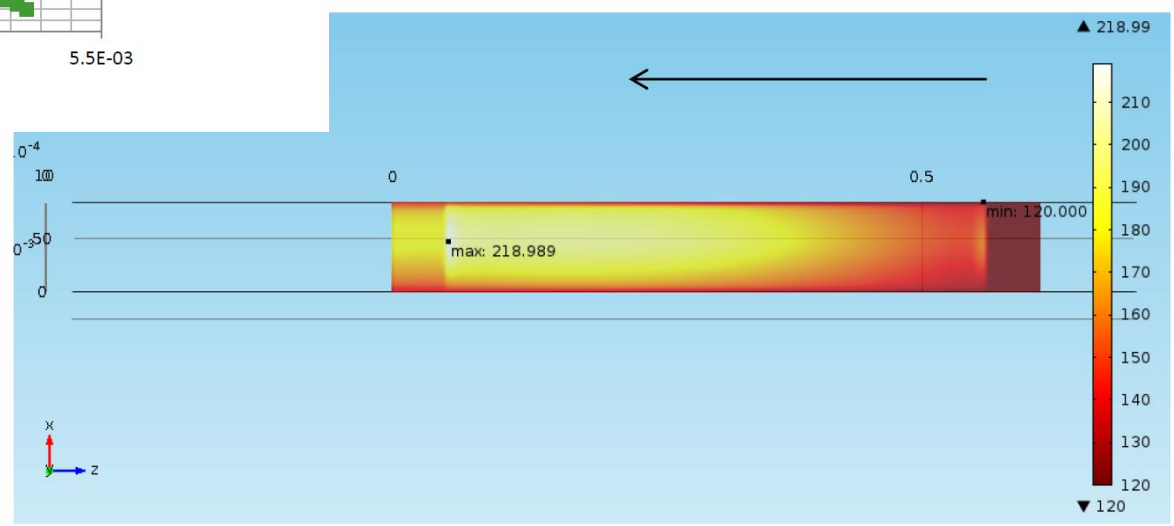
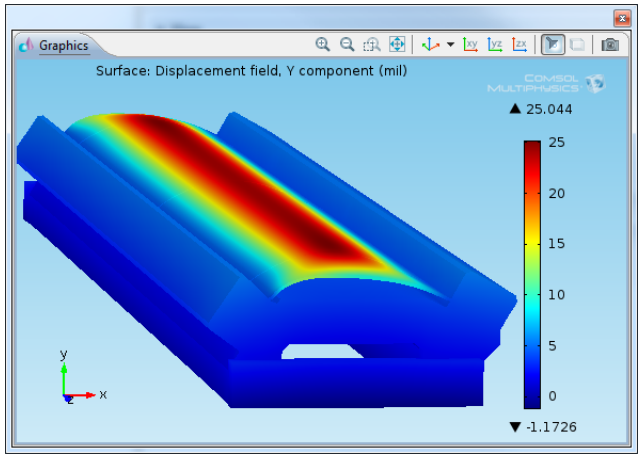
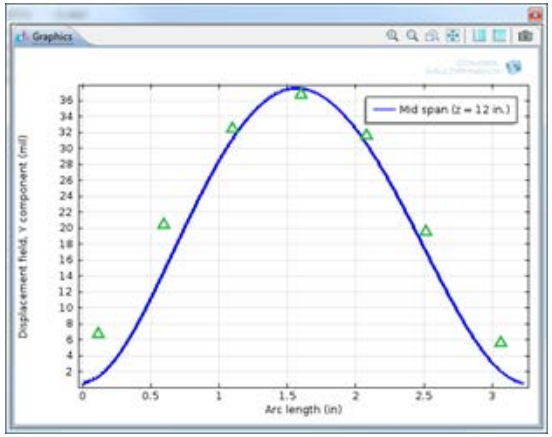
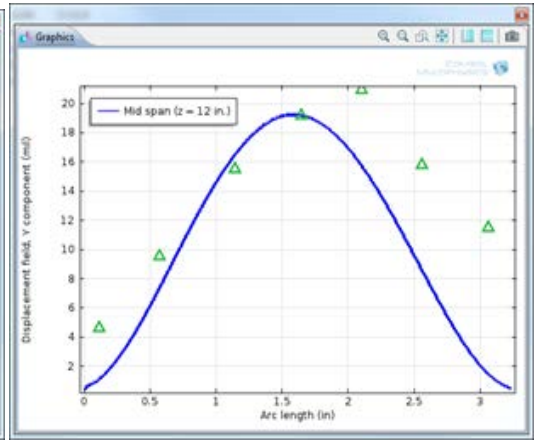


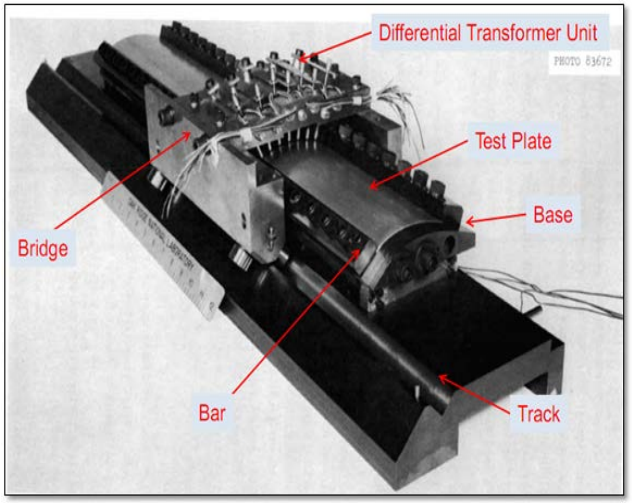
Figure 4. Fuel Plate Surface Temperature [°F]. The black arrow indicates flow direction.

COMSOL is Benefiting the HFIR LEU Conversion Project – thermal-structure interaction V&V



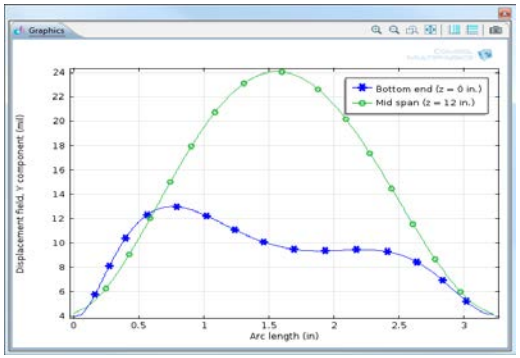


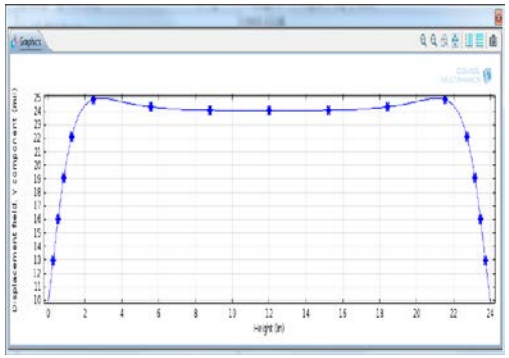




Comparison of mid-span deflections of an aluminum plate attached with Invar (a) solid and (b) split bases with experimental results.

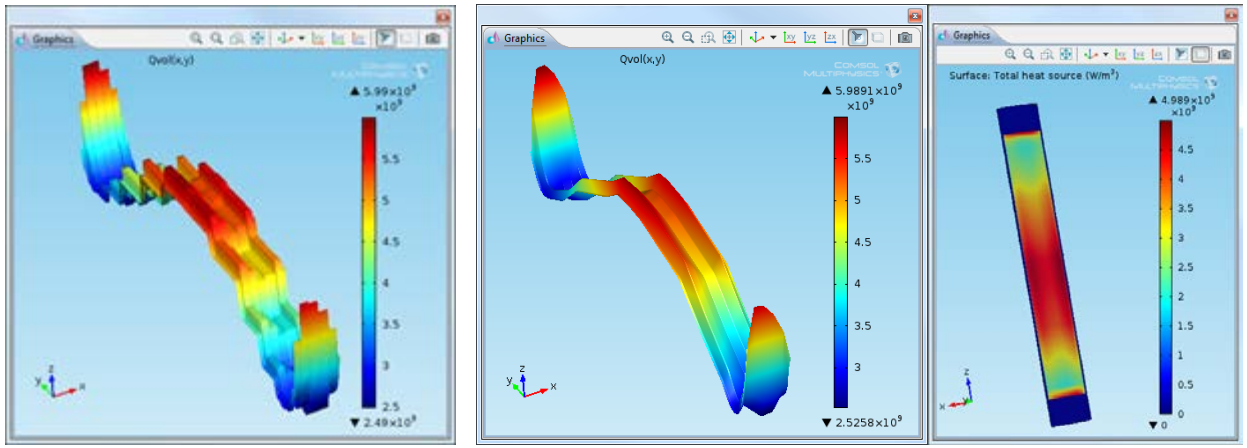
ORNL/TM-2012/138, Jain et al.





Research performed by ORNL Research Staff Member Prashant K. Jain

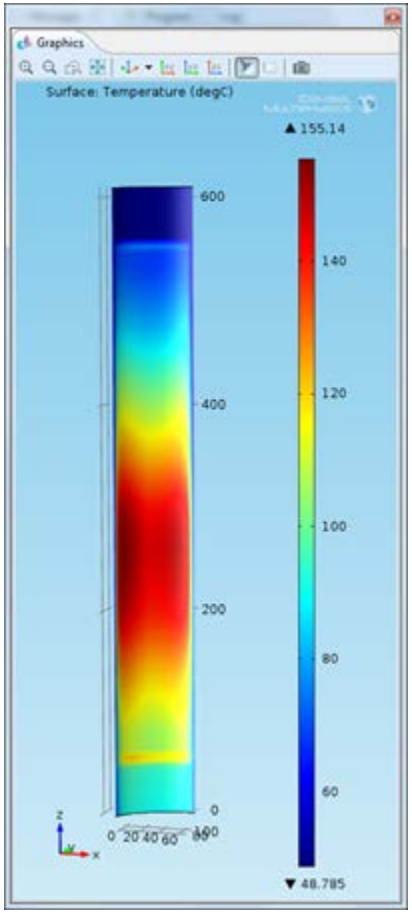
COMSOL is Benefiting the HFIR LEU Conversion Project – sensitivity studies and production 3D



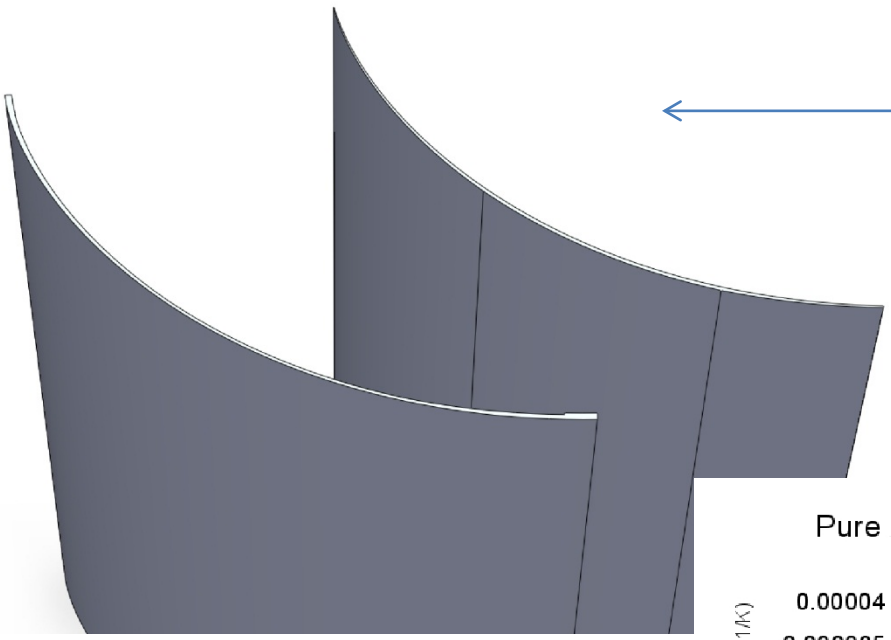
Heat generation in an axially non-graded LEU fuel. (a) Heat source slices as provided by MCNP results (19 axial, 8 radial); (b) COMSOL generated smoothing using linear interpolation; (c) Volumetric heat source as provided to a LEU fuel plate (notice the non-fueled region in the top and bottom, and near the side plate edges in the longitudinal direction).

Research performed by ORNL summer intern Vaibhav B. Khane (UM-Rolla) and ORNL mentor Prashant K Jain

Clad surface temperature (℃) for the LEU fuel plate in nominal HFIR conditions for an axially non-graded LEU fuel.

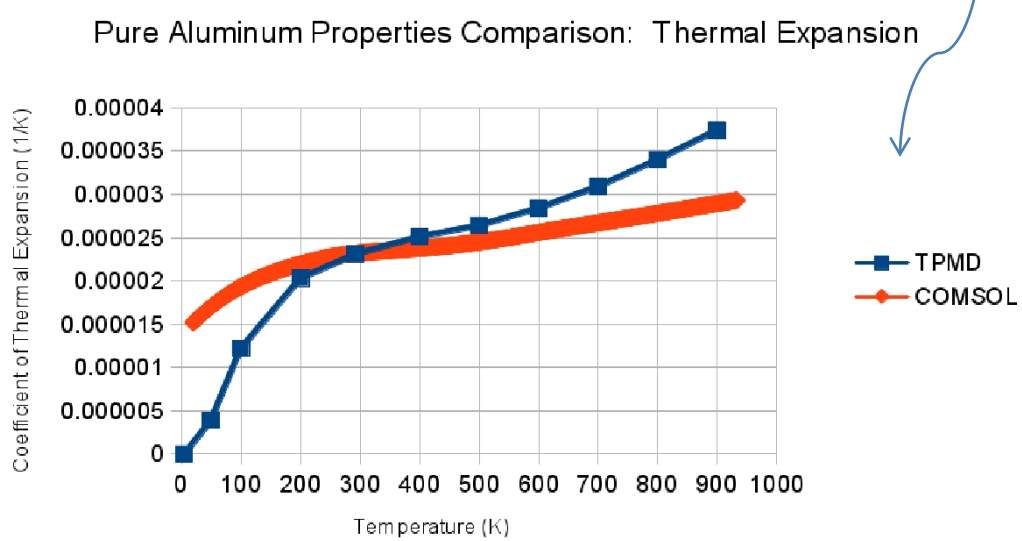


COMSOL v4.3 will soon be approved for nuclear-safety related calculations at HFIR: SBP-1300 SQA verification



Solidworks CAD import of HFIR involute fuel plates

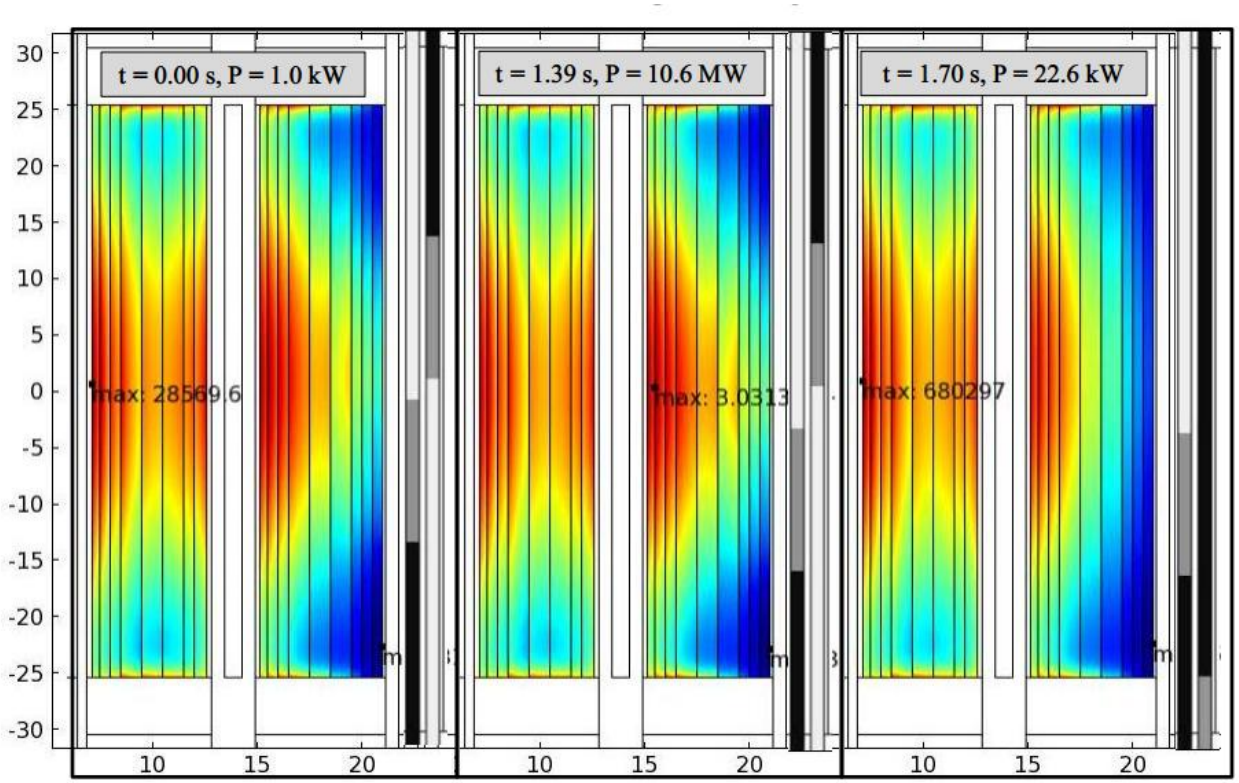
COMSOL Material library Comparison To TPMD



development being performed by

Adam R. Travis
UTK-MABE MS student
presently summer intern

COMSOL Equation-Based Modeling at HFIR



Power shifts to the OFE during control cylinder ejection and then back to IFE during safety plate insertion.

COMSOL-based Nuclear Reactor Kinetics Studies at the HFIR, Best Paper, 2011 COMSOL Conference Boston

Spatially-Dependent Reactor Kinetics and Supporting Physics Validation Studies at the High Flux Isotope Reactor, PhD Dissertation, UTK-NE, August, 2011

David Chandler
UTK-NE PhD graduate
ORNL Research Staff - RRD

Conclusions and Current Status

- **COMSOL is providing a modern simulation tool for HFIR-related projects including (a) design of LEU fuel (b) analysis of present HEU fuel, and (c) analysis of Pu-238 targets**
- **COMSOL analysis provides details and accuracy heretofore not possible, and allows for precise margin estimates.**
- **COMSOL results demonstrate methods that yield accurate benchmarks with established data bases (V&V).**
- **Evolving toward routine nuclear-SQA approval of COMSOL for subsequent versions.**
- **COMSOL is providing a tool by which graduate-level engineering students may engage in research as part of their degree requirements.**