ORNL Nuclear Simulation and Analysis and Opportunities for You...

Kevin Clarno

clarnokt@ornl.gov

Nuclear Science & Technology Division

Oak Ridge National Laboratory

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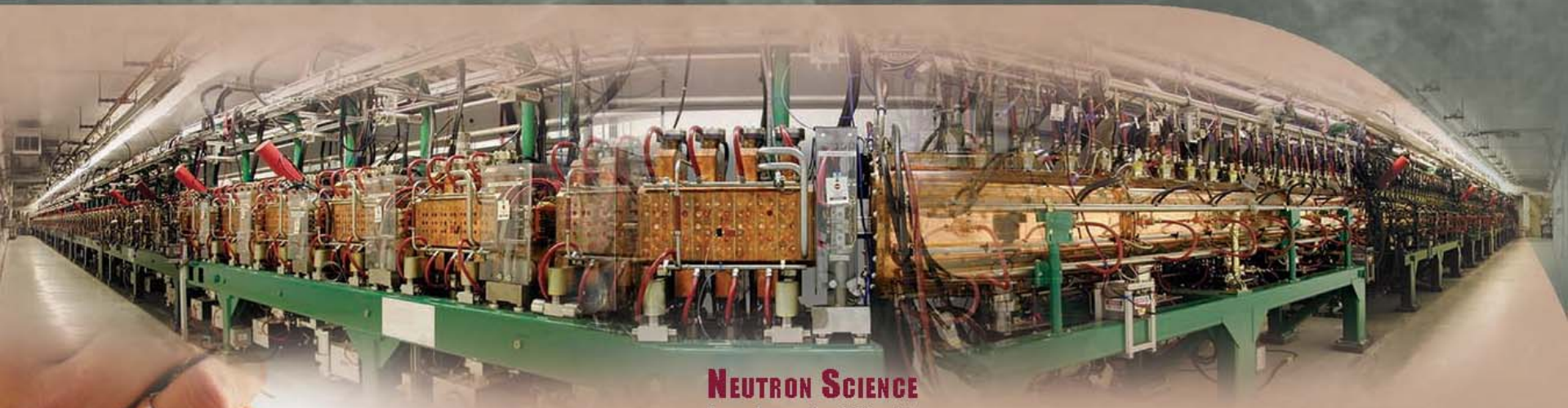
ANS Seminar

The University of Texas

Six Scientific Themes

Born of necessity. Inspired by our quest to know. We have always been called upon to address America's greatest scientific challenges.



Neutron Science
Leading the World

The Spallation Neutron Source and the High Flux Isotope Reactor together make Oak Ridge the world's foremost center for neutron science.
andersonian@ornl.gov

Biological Systems
Developing New Options

Whether converting biomass to fuel or understanding the impacts of climate change, biological research at ORNL is helping develop new options for energy, environmental protection, and human health. **mannre@ornl.gov**

Advanced Materials
Strengthening American Industry

With DOE's first Nanoscience Center, the world's most powerful electron microscope, and the High Temperature Materials Laboratory, Oak Ridge plays a critical role in American industrial competitiveness.
buchananmv@ornl.gov

"Men love to wonder, and that is the seed of science."

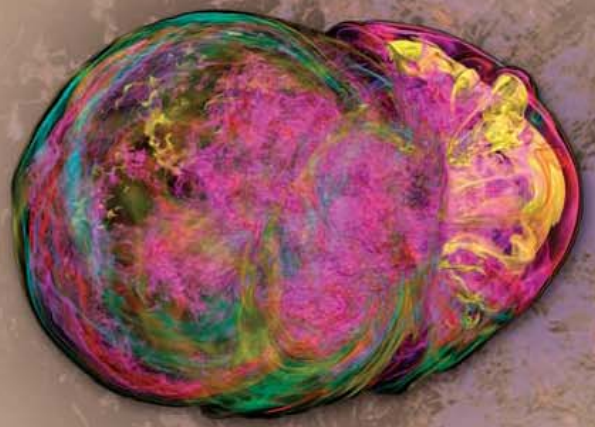
. . . Ralph Waldo Emerson

National Security

Guarding the Gates

From biochemical sensors to stopping the proliferation of nuclear weapons, technologies that make America safer are among the laboratory's top research priorities.

akersfhjr@ornl.gov



High Performance Computing

Tackling the Big Problems

With unmatched computational capacity for open scientific research, Oak Ridge is on a path by 2009 to reach a peta□op, or 1 quadrillion mathematical calculations per second, making it possible to model the most complex scientific problems.

zachariat@ornl.gov

Energy

Providing Energy Alternatives

Increased production, improved transmission, reduced consumption: Oak Ridge is addressing our energy challenges on all fronts, from safer nuclear power to more energy-e□ cient cars and homes.

christensend@ornl.gov

Nuclear @ ORNL

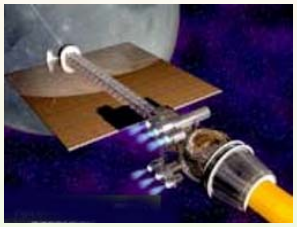
- **Nuclear Science & Technology Division**
  - **All things nuclear**
    - **SCALE nuclear analysis code suite**
- **Space Nuclear Power Program**
  - **Electricity generation, propulsion, shielding, materials**
- **Fusion Engineering Division**
  - **Teamed with Princeton as the US lead for ITER**
- **Spallation Neutron Source**
  - **Neutron and atomic physics**
- **Research Reactor Division (HFIR)**
  - **Materials testing, irradiation research, and isotope production**
- **Radiation biology, medical physics, astrophysics, etc.**

Nuclear Science and Technology Division

NUCLEAR SECURITY TECHNOLOGIES

- Material protection, control, and accounting
- Safeguards
- Arms control assessments
- Export control
- Nuclear threat reduction
- Radiation detection
- Radiation transport
- Transportation technologies
- Fissile material detection
- Fissile material disposition
- Instrumentation

NUCLEAR SYSTEMS ANALYSIS, DESIGN, AND SAFETY



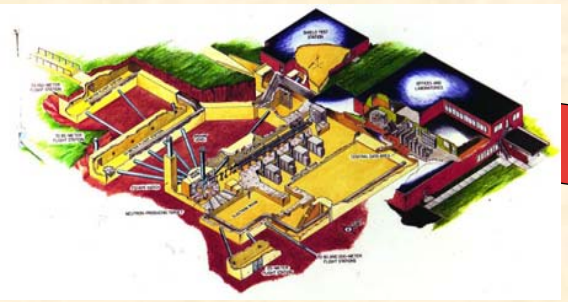
- Nuclear data and codes
- Criticality safety
- Reactor physics
- Radiation shielding
- Advanced/Space reactors
- Thermal hydraulics
- Material and fuel irradiation
- Information/Systems analysis
- Facility safety
- Risk assessment
- Regulatory support
- System instrumentation and controls
- Enrichment technology

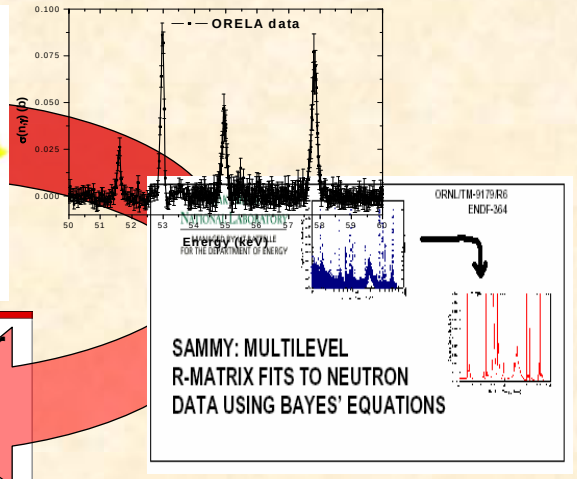
FUELS, ISOTOPES, AND NUCLEAR MATERIALS

- Nuclear fuels
- Heavy element production
- Stable/radioactive isotopes
- Medical isotope development
- Separations science and technology
- Nuclear process and equipment design
- Robotics
- Remote handling
- Chemical engineering

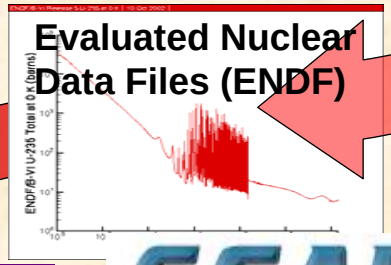
SCALE @ ORNL: Science to Applications

science





Evaluated Nuclear Data Files (ENDF)



computational modeling

AMPX

SCALE

applications

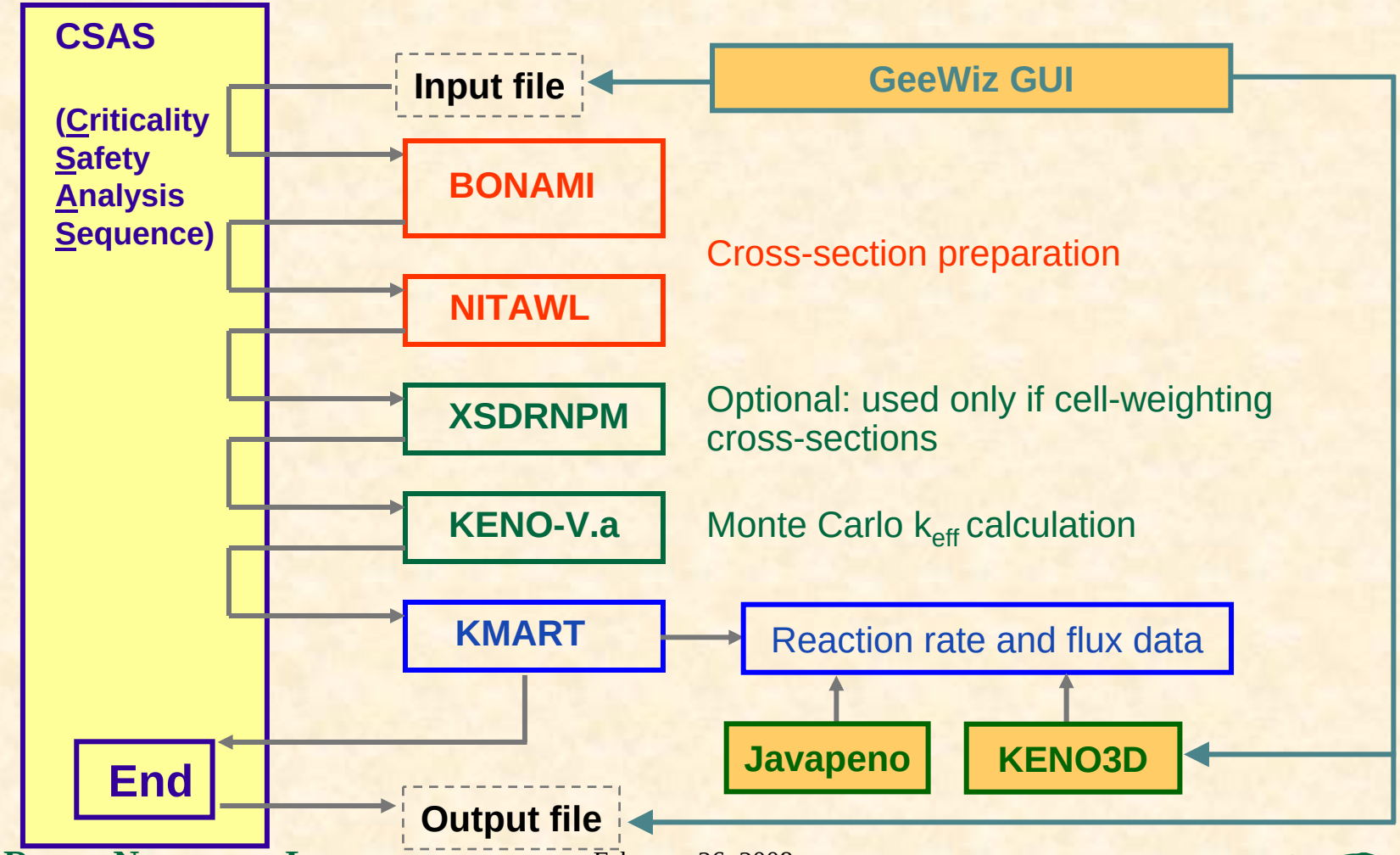
Interface science (the basic physics of cross-section measurements), computational modeling (SCALE), and applications expertise to support evaluation and resolution of nuclear engineering and safety issues.

- Cross-section processing
- Criticality safety
- Radiation protection and shielding
- Reactor physics
- SNF/waste characterization (e.g., inventory, decay heat, radiation source and spectra)

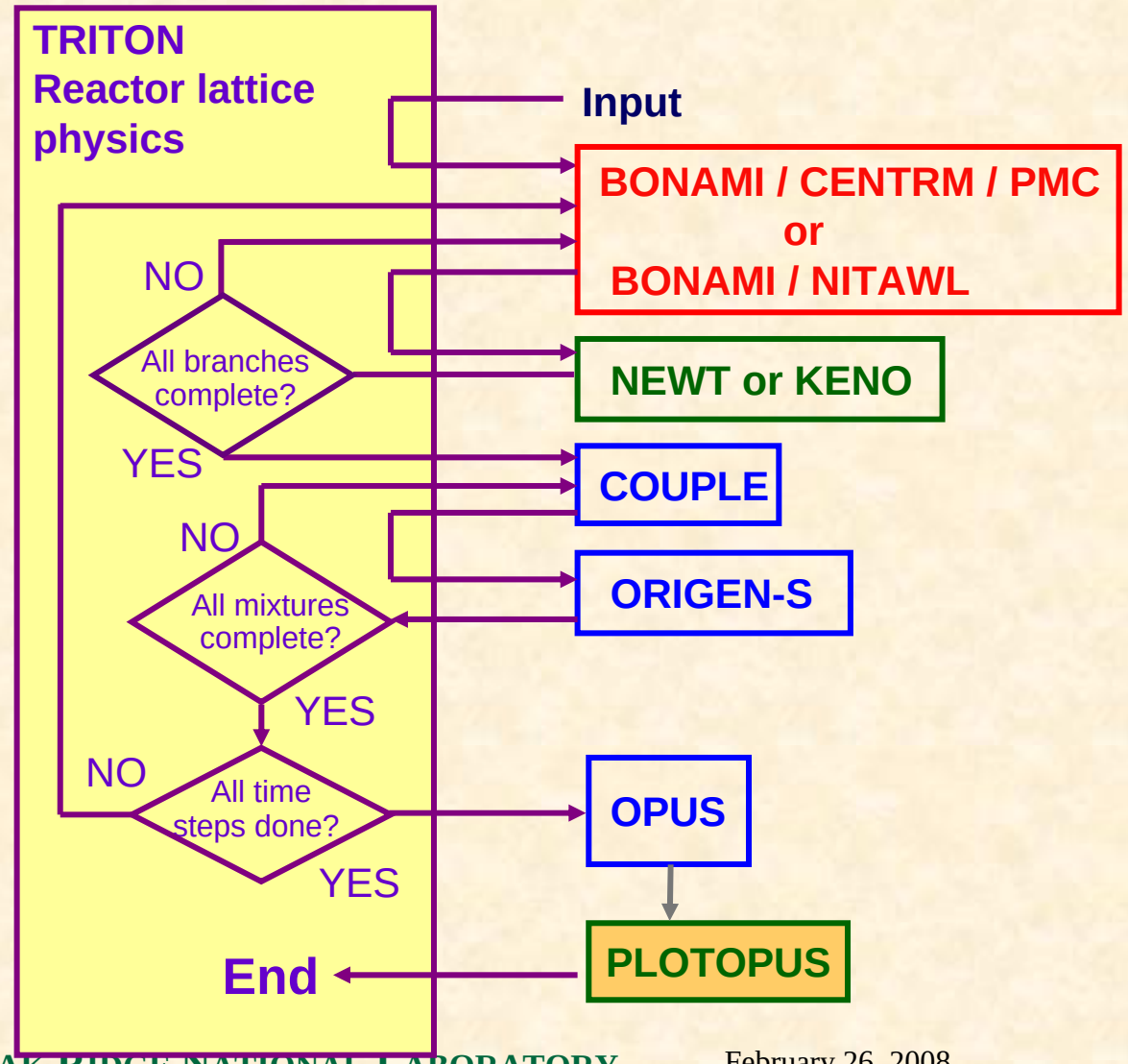
There are many codes within SCALE

Input & Visualization	Multi-Group Cross Sections	Radiation Transport	Feedback & Coupling	Drivers to Simplify
GeeWiz	BONAMI	KENO-CE	ORIGEN-S	TRITON
KENO-3D	NITAWL	KENO	STARBUCS	CSAS
JAVAPENO	CENTRM	MONACO	OPUS	SAS
PLOTOPUS	PMC	TORT	KMART	TSUNAMI
	GEMINEWTRN	NEWT		
		XSDRN-PM		

SCALE is built on a Modular Concept



Some drivers make many decisions



Resonance cross-section processing (repeat for all cells)

2-D discrete ordinates or 3-D monte carlo

Fuel depletion/decay (repeat for all depletion mixtures)

Output edits (repeat for all requested mixtures)

Plot of isotope concentration with time

From Data to Cross Sections: Resonance Self-Shielding

- BONAMI: **Bondarenko Method**
  - *Tabulated correction factor for temperature & concentration of an isotope*
  - *Generally used in the unresolved energy range only*

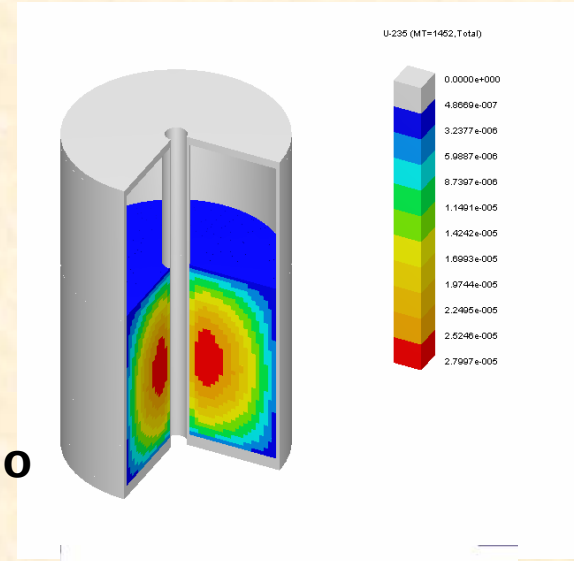
- NITAWL: **Nordheim Integral Treatment**
  - *Every resonance is treated independently*
  - *Approximates problem-dependent geometry & material affects*
  - *Fast, good accuracy with few high concentration isotopes (< ENDF/B-VI)*

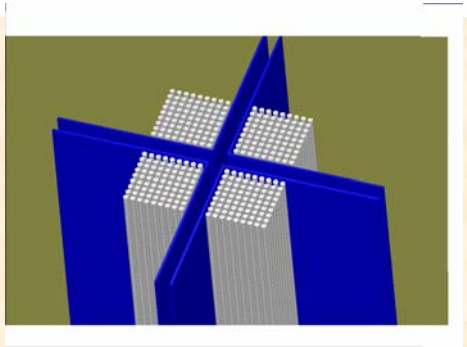
- CENTRM: **C**ontinuous **EN**ergy **TR**ansport **M**odule

  for resolved resonance range (all libraries: ENDF/B-VI)
  - **Performs 1-D S_n calculation for continuous-energy neutron spectra using with Point-Wise nuclear data**
  - **Processes problem-dependent multigroup XS's using Point-Wise nuclear data and flux spectrum**

SCALE Stochastic Transport Methods

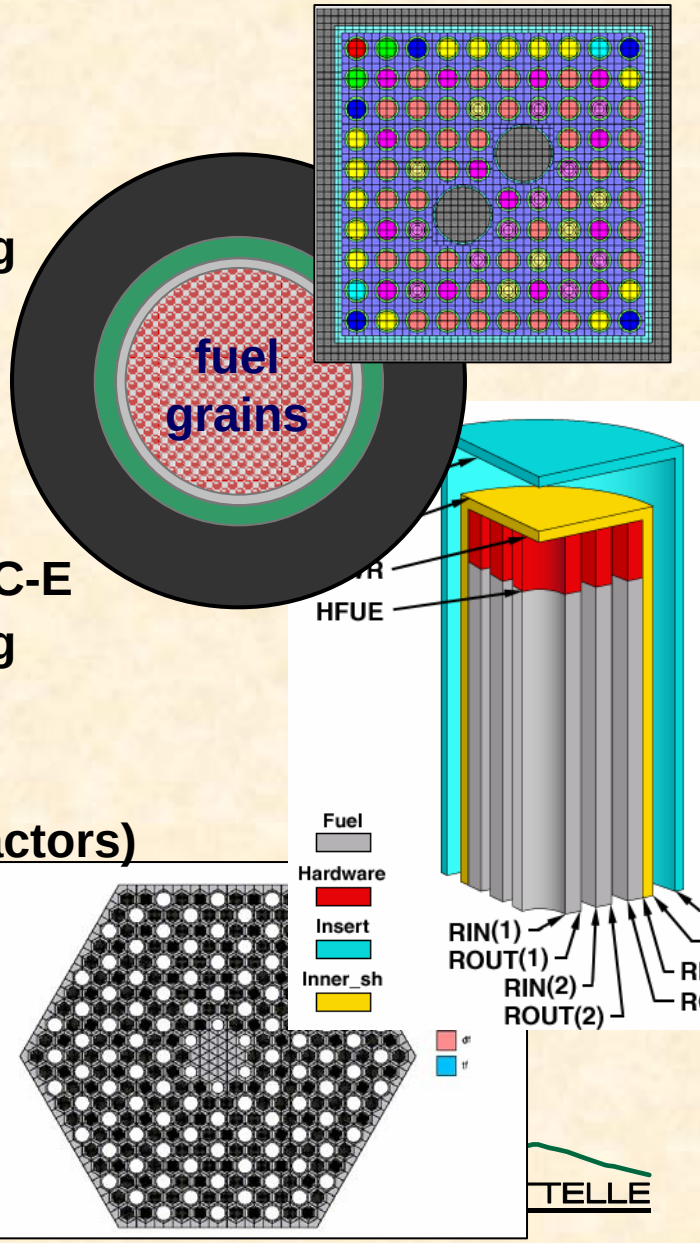
- **KENO-5 and KENO-VI multi-group Monte Carlo codes**
  - Developed for criticality safety applications
  - Much faster than continuous energy
  - Now integrated with TRITON for depletion
- **Continuous Energy KENO**
  - Currently under development
  - Provides the rigor of continuous energy Monte Carlo
- **MORSE/MONACO Monte Carlo Shielding**
  - Advanced variance reduction
- **A Single Consistent Geometry**
  - SCALE Generalized Geometry Package (SGGP) being adopted for all ORNL codes
  - Easily switch from NEWT to KENO-VI to CE-KENO





SCALE Deterministic Transport Methods

- **CENTRM**
  - 1-D, source-driven, continuous-energy
  - For problem-dependent resonance processing
- **XSDRN-PM**
  - 1-D, WDD, multi-group
  - Forward/adjoint with a host of uses
- **GEMINEWTRN**
  - 2-D arbitrary polygonal mesh, source-driven, C-E
  - For problem-dependent resonance processing
- **NEWT**
  - 2-D arbitrary polygonal mesh, multi-group
  - Forward/adjoint solutions for all analyses (reactors)
- **TORT**
  - 3-D orthogonal mesh, multi-group
  - For all analyses, widely-used in shielding



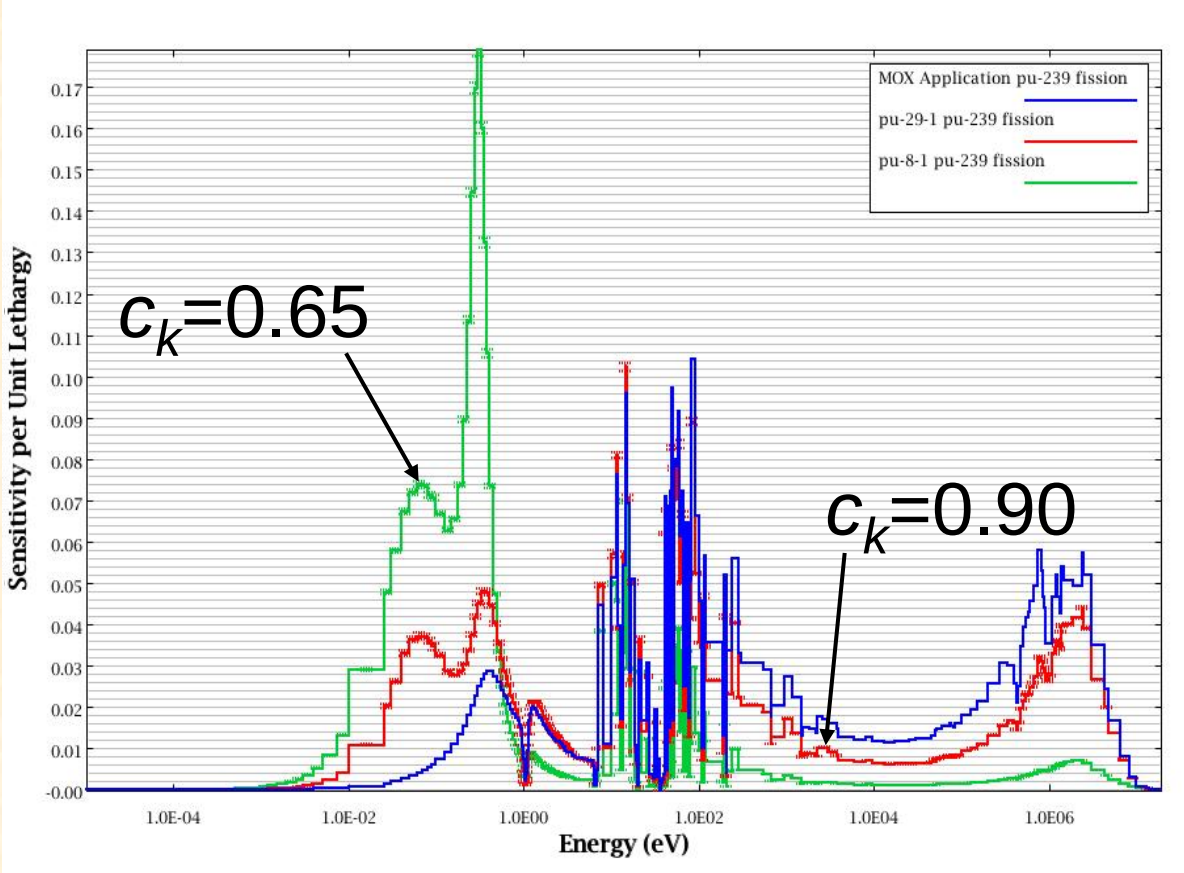
ORIGEN-S: Irradiation and decay simulation code

- **Irradiation and decay simulation code**
- **Explicit simulation of 1484 unique nuclides (1946 nuclides in database)**
  - **129 actinides**
  - **1119 fission products**
  - **698 structural activation materials**
  - **Other depletion codes typically track a minimum subset of isotopes that are important for reactivity**
- **Detailed radionuclide compositions**
- **Decay heat sources (neutron/photon), including energy spectra**
- **Radio-toxicity**
- **One of few codes available with comprehensive isotopic characterization of fuel over time scale of seconds to millennia**
  - **Accident analyses**
  - **Storage and handling**
  - **Transportation**
  - **Disposal or reprocessing**
  - **Repository analysis (storage, migration, dose assessment)**

TSUNAMI: Tool for S/U Analysis with XSDRN (1-D) and KENO-VI (3-D)

- **Determination of critical experiment benchmark applicability to nuclear criticality safety analyses**
- **The design of critical general physics experiments (GPE)**
- **The estimation of computational biases and uncertainties for the determination of safety subcritical margins**

^{239}Pu Fission Sensitivity Profiles: Sensitivity of k_{eff} to cross-section



That is what we have…
but what are we doing?

- **Analysis**
  - **Reactors**
    - **Gen-IV / GNEP (DOE)**
      - **AHTR**
    - **Gen-III, III+ (NRC)**
    - **Space Reactors (NASA)**
  - **Shielding / criticality safety**
    - **Transportation**
    - **Space**
    - **Facilities**
  - **Optimization and S/U**
    - **GA system optimization**
    - **S/U of design on nuclear data**
  - **Others**
    - **Medical physics**
    - **Yucca mountain**
    - **Nuclear materials**
- **Code Development**
  - **Incorporation and integration**
    - **Generalized geometry input**
    - **TORT within SCALE**
    - **TSUNAMI with NEWT/TRITON**
  - **Incremental improvements**
    - **MONACO variance reduction**
    - **Uncertainty propagation**
    - **ORIGEN-S improvements**
    - **Many others…**
  - **High-performance computing**
    - **Multi-physics Reactor Simulation**
    - **Multi-physics Fuel Simulation**
    - **Genetic Algorithm Design Optimization**

Your opportunities at ORNL

- **NESLS – Physics & Engineering Students**
  - **Nuclear Science & Technology Division**
  - **Highly competitive stipends**
  - www.ornl.gov/sci/nuclear_science_technology/nstip/internship.htm
- **SULI – Nuclear Engineering Students**
  - **Less competitive, but only $475/week**
  - **http://www.scied.science.doe.gov/SciEd/erulf/about.html**
- **Full-time Staff and Post-Doc Positions**
  - **http://jobs.ornl.gov/**
  - **Radiation Transport and Criticality Group**
    - **2694, 2695, 2696**
  - **Advanced Reactor Systems and Safety Group**
    - **2538**
  - **Reactor Analysis Group**
    - **Two are soon to be posted**
- **SCALE is cheap**
  - **Source code is free to NE students and faculty**
  - **Training is only ~$500 (cheap for a professor)**

NESLS	Weekly Stipend
First Year (Freshman)	$634
Second Year (Sophomore)	$698
Third Year (Junior)	$758
Fourth Year (Senior)	$831
Fifth Year (Graduate)	$968
Masters Completed	$1040

Conclusions

- **ORNL has a complete set of nuclear analysis tools**
  - **Nuclear data and data analysis**
  - **Advanced cross section generation techniques**
  - **Deterministic & stochastic transport with CE and MG**
  - **Sensitivity and uncertainty propagation and assessment**
- **We are utilizing these tools for many applications**
  - **Reactors: air, land, and sea**
  - **Shield design & criticality safety**
  - **Fuel performance, waste and transportation**
- **You can join us to learn in a 3-month job interview, explore Knoxville and the Smokies, and get paid very well**