U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Nuclear Data and Safety

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Office of Research

USNRC - Authority

- NRC's legislated authority is summarized in NUREG-0980 "Nuclear Regulatory Legislation"
  – ADAMS No: ML13274A489
- Some Key legislation
  – Atomic Energy Act of 1946:
    - How technology will be used
  – Atomic Energy Act of 1954
    - Allowed for commercial nuclear reactors
  – Energy Reorganization Act of 1974
    - Established the US-NRC

USNRC - Mission

- Mission

“The NRC licenses and regulates the Nation's civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security and to protect the environment” (https://www.nrc.gov/about-nrc.html)

- In another way, an aspect to this is to understand, control and predict the behavior of systems that contain radioactive material

Mission Starts with Nuclear Data

- The NRC mission is fulfilled through fundamental data that is appropriate to both the system and the characteristic phenomena for that problem. This basic phenomelogical understanding provides the possibility for reasonable predictions of system state, and time dependent behavior
- Complete and quality nuclear data supports both design and safety models. These models then allow for interrogating the safety efficacy
- Safety scenarios that nuclear data may impact include:
  - Fuel overheat scenarios
    - Loss of coolant, dilution events (over moderation), pump trip, etc
  - Reactivity Insertion scenarios
    - Control rod ejection, boron dilution, moderator cooldown, etc
  - Configuration scenarios
    - Fresh and burned fuel placement in a spent fuel rack, cask, refueling, etc
  - Decay heat scenarios:
    - Sizing of safety systems, etc
  - Reactivity control scenarios:
    - Shutdown margin, relative worth of boron and control rods over a cycle, how delayed critical a core is (Beff), post-trip Xe worth, MTC, DTC, etc

Typical Nuclear Data

- Needs:
  - Reaction rates for isotopes of interest
    - Includes thermal scattering law
  - Fission product yields
  - Decay constants
  - Understand the uncertainties of and the correlations between the nuclear data (covariance matrices)
  - Understand the impacts of any gaps in the data for an application system
  - Understand the changes in data between ENDF libraries, and how that data was developed
  - etc

SCALE, NRC's Swiss Army Knife

- SCALE is used to process nuclear data
- Extensive use in various regulatory applications
- Domestic and international users – over 9,600 licenses in 61 nations issued for SCALE through January 2020 (over 2,300 licenses for SCALE 6.2 since its release in April 2016); including 33 foreign regulators
- SCALE (and AMPX) are the direct consumers of nuclear data which supports various NRC analyses
  - Generate lattice parameters for PARCS analysis to support for example the MELLLA+ power uprate at operating reactors
  - Generate nuclides inventories and decay heat for thermal-hydraulics and severe accident/source term analysis
  - Perform confirmatory analysis (criticality, decay heat and shielding) for licensing spent fuel casks and radioactive material transportation packages.
  - Perform shielding and materials activation analysis
  - Initializes other computer codes, such as PARCS, TRACE/Parcs, MELCOR, MACCS, FAST, UNF-ST&NDARDS templates

Nuclear Data, SCALE, and Regulatory Impact

- 10 CFR Part 100: Reactor Site Criteria
- 10 CFR Part 76.89: Criticality Accident Requirements (GDP)
- 10 CFR Part 74: Material Control and Accounting of Special Nuclear Material
- 10 CFR Part 72: Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste
- 10 CFR Part 71: Packaging and Transportation of Radioactive Material
- 10 CFR Part 70: Domestic Licensing of Special Nuclear Material
- 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories
- 10 CFR Part 50: General Design Criteria for Nuclear Power Plants

Transportation and storage licensing at NRC

analysis end-points

ENDF/B
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, etc.

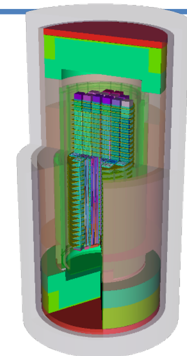
JEFF Activation
Isomeric cross sections, activation reactions

Sources4C
neutron emission data (alpha,n)

ICRP
dose conversion factors, radiotoxicity

NIST
natural abundance, atomic mass

scale
Nuclear Systems Modeling & Simulation



AMPX
Validated cross section libraries in multigroup (O(100g)) or continuous-energy (O(100,000g); depletion and decay data

ORIGEN
General depletion, decay, source term

TRITON
General reactor fuel neutron transport + depletion

MAVRIC
3D shielding and dose rate analysis

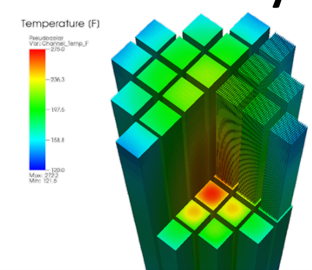
CSAS
3D criticality safety analysis

ORIGAMI
Reactor-specific radioactive isotopics/source term characterization

Structural analysis

ANSYS / LS-DYNA
Commercial finite element analysis

Thermal analysis



STAR-CCM+ / FLUENT
Commercial computational fluid dynamics codes

Reactor physics confirmatory analysis at NRC

analysis end-points

ENDF/B
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, decay energy

JEFF Activation
Isomeric cross sections, activation reactions

Kinetics Data
nuclide-specific beta-effective, neutron precursor data

Energy Release Data
nuclide-specific energy per capture/fission

NIST
natural abundance, atomic mass

scale
Nuclear Systems Modeling & Simulation

AMPX
Validated cross section libraries in multigroup (O(100g)) or continuous-energy (O(100,000g); depletion and decay data

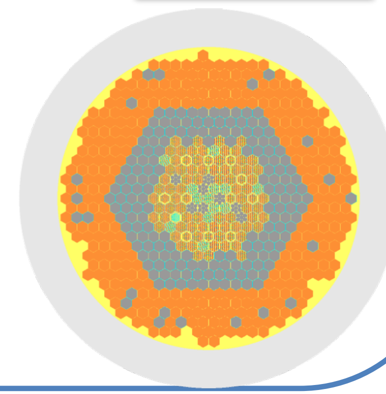
Polaris
Fast LWR lattice physics

TRITON
General 3D reactor fuel neutron transport + depletion

PARCS
Advanced core simulator
Neutron flux solver and depletion

TRACE
System level temperature distributions and feedback

FAST
Fuel performance



Severe accident & consequence analysis at NRC

analysis end-points

ENDF/B
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, etc.

JEFF Activation
Isomeric cross sections, activation reactions

Sources4C
neutron emission data (alpha,n)

Kinetics Data
nuclide-specific beta-effective, precursor data

NIST
natural abundance, atomic mass

scale
Nuclear Systems Modeling & Simulation

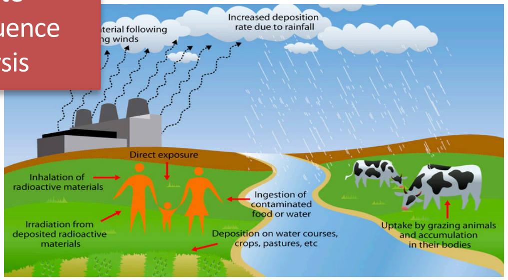
AMPX
Validated cross section libraries in multigroup (O(100g)) or continuous-energy (O(100,000g); depletion and decay data

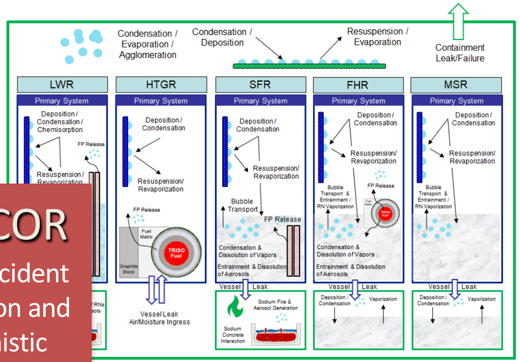
ORIGEN
General depletion, decay, source term

TRITON
General reactor fuel neutron transport + depletion

ORIGAMI
Reactor-specific radioactive isotopics/source term characterization

MACCS
Offsite consequence analysis





MELCOR
Severe accident progression and mechanistic source terms

“NRC Non-Light Water Reactor Vision and Strategy, Volume 3 – Computer Code Development Plans for Severe Accident Progression , Source Term, and Consequence Analysis,” Revision 1, January 2020, ML20030A178

Nuclear Data - What Are We Doing

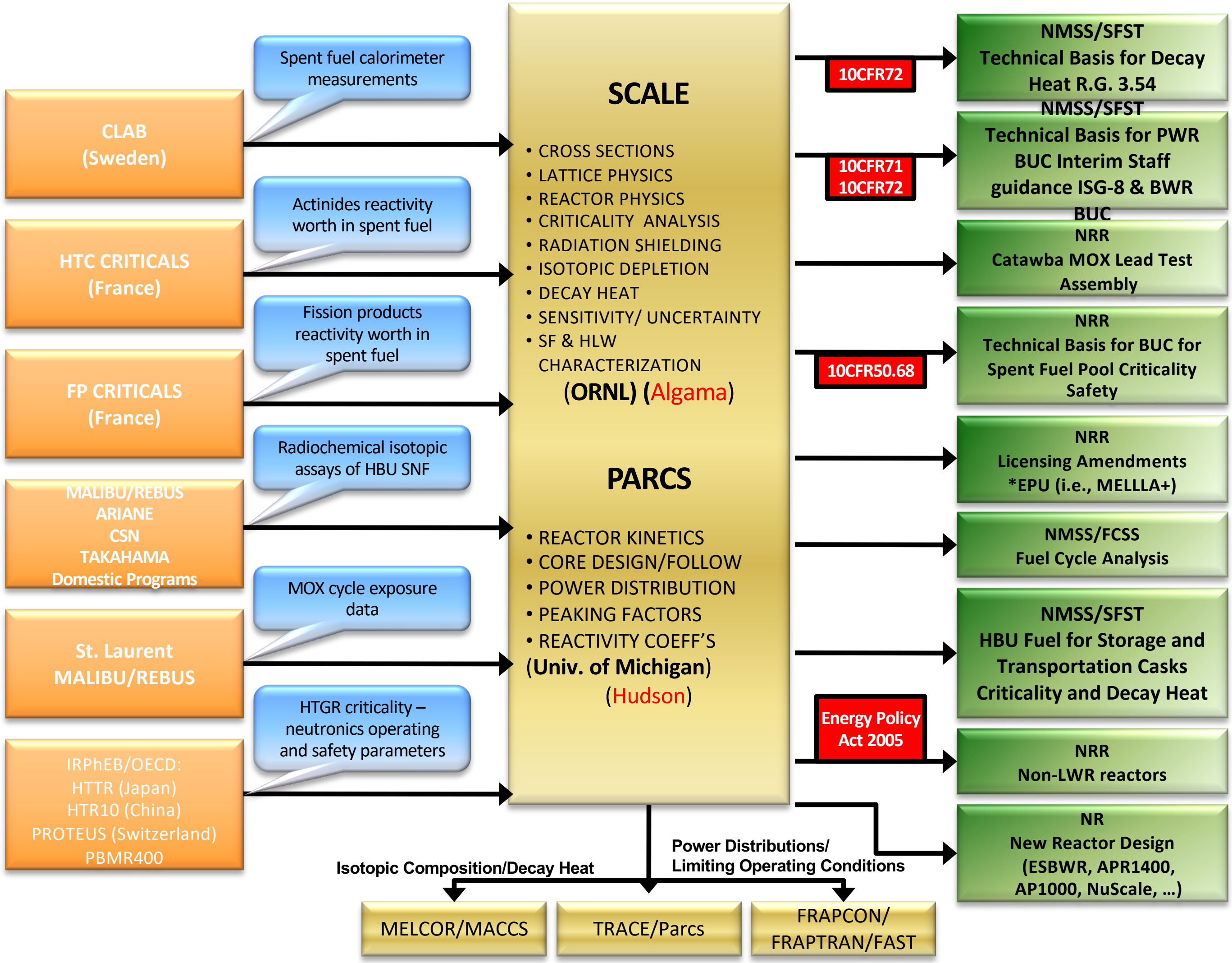
- Basic Research
  - Assessing performance of ENDF/B-VII.1 vs. ENDF/B-VIII.0 (including uncertainty data) for diverse applications
  - Updating independent FP yields (ENDF/B-VIII.0) to be consistent with decay data/cumulative yields
  - Introducing data correlations to reduce integral uncertainties (more consistent with observed biases)
- Standard Light Water Reactor (LWR)
  - Extending nuclear data in SCALE with uncertainty (kinetics)
  - Improving SAMPLER (SCALE's arbitrary uncertainty propagation engine), e.g. additional sensitivity indices, correlation calculations
- LWR/Accident Tolerant Fuel (ATF), High Burnup (HBU), High Assay Low-Enriched Uranium (HALEU)
  - Assessing isotopics/reactivity for ATF, HBU and HALEU systems related to standard LWR
  - Performing similarity assessments to understand criticality validation basis
  - Developing new methods for isotopics validation basis
- NonLWR
  - Assessing important nuclear data for nonLWR systems--anything new/different compared to LWRs
  - Affect on safety-related parameters (power peaking factors, reactivity coefficients, delayed neutron fraction)
  - Affect on severe accident analysis (isotopics, reactivity coefficients)

Summary

- Staff recognize the importance of high-quality nuclear data as the foundation for reliable and robust nuclear systems analysis
- NRC actively drives development of the SCALE system to support confirmatory analyses for LWR (including ATF, HBU and HALEU related activities) and Non-LWR (nuclear data and applications space)
- Nuclear data collection (e.g. measurements), evaluation (e.g. ENDF/B), processing for use in software (e.g. AMPX), and application (e.g. SCALE) must strive for
  - transparency and reproducibility,
  - robust handling of uncertainty (including correlations), and
  - rigorous validation which leads to understanding of bias+bias uncertainty (nuclear data and otherwise) for real analysis scenarios.
- My colleague, Will Wieselquist who is the SCALE Director, will be speaking later in more detail on Reactor Physics Data Needs

Thank you

Extra


CLAB (Sweden)
HTC CRITICALS (France)
FP CRITICALS (France)
MALIBU/REBUS
ARIANE
CSN
TAKAHAMA
Domestic Programs
St. Laurent MALIBU/REBUS
IRPhEB/OECD:
HTTR (Japan)
HTR10 (China)
PROTEUS (Switzerland)
PBMR400
Spent fuel calorimeter measurements
Actinides reactivity worth in spent fuel
Fission products reactivity worth in spent fuel
Radiochemical isotopic assays of HBU SNF
MOX cycle exposure data
HTGR criticality – neutronics operating and safety parameters
SCALE
• CROSS SECTIONS
• LATTICE PHYSICS
• REACTOR PHYSICS
• CRITICALITY ANALYSIS
• RADIATION SHIELDING
• ISOTOPIC DEPLETION
• DECAY HEAT
• SENSITIVITY/ UNCERTAINTY
• SF & HLW CHARACTERIZATION
(ORNL) (Algama)
PARCS
• REACTOR KINETICS
• CORE DESIGN/FOLLOW
• POWER DISTRIBUTION
• PEAKING FACTORS
• REACTIVITY COEFF'S
(Univ. of Michigan)
(Hudson)
10CFR72
10CFR71
10CFR72
10CFR50.68
Energy Policy Act 2005
NMSS/SFST
Technical Basis for Decay Heat R.G. 3.54
NMSS/SFST
Technical Basis for PWR BUC Interim Staff guidance ISG-8 & BWR BUC
NRR
Catawba MOX Lead Test Assembly
NRR
Technical Basis for BUC for Spent Fuel Pool Criticality Safety
NRR
Licensing Amendments *EPU (i.e., MELLLA+)
NMSS/FCSS
Fuel Cycle Analysis
NMSS/SFST
HBU Fuel for Storage and Transportation Casks Criticality and Decay Heat
NRR
Non-LWR reactors
NR
New Reactor Design (ESBWR, APR1400, AP1000, NuScale, …)
Isotopic Composition/Decay Heat
Power Distributions/ Limiting Operating Conditions
MELCOR/MACCS
TRACE/Parcs
FRAPCON/ FRAPTRAN/FAST