Summary of Nuclear Data Needs for X-Energy Reactor Designs

Presented to:
Workshop on Applied Nuclear Data Activities (WANDA)

Dr. Bradley T. Rearden
Director of Engineering, Xe-Mobile

February 1, 2021

X-energy was Created to Change the World

Dr. Kam Ghaffarian,
Founder and Executive Chairman

"President Kennedy once said that we are in a space race and my work with NASA reflects the progress he had hoped for.

Today, I believe we are in an energy race. Providing clean energy across the world is my vision for X-energy and I believe that clean, safe, reliable nuclear energy is necessary to making this possible."

- Dr. Kam Ghaffarian is a globally recognized technology visionary across energy, space and information technology.

Stinger Ghaffarian Technologies

- Created and grew Stinger Ghaffarian Technologies (SGT), Inc. to $650 million in annual revenue and 2,400 employees. SGT was ranked as the U.S. National Aeronautics and Space Administration's second largest engineering services company prior to being acquired by KBRwyle, subsidiary of KBR, Inc.

energy

- Founded X-energy in 2009 to address innovation in critical energy solutions. X-energy was awarded ~$60M from DOE to focus on an advanced nuclear reactor and TRISO fuel.

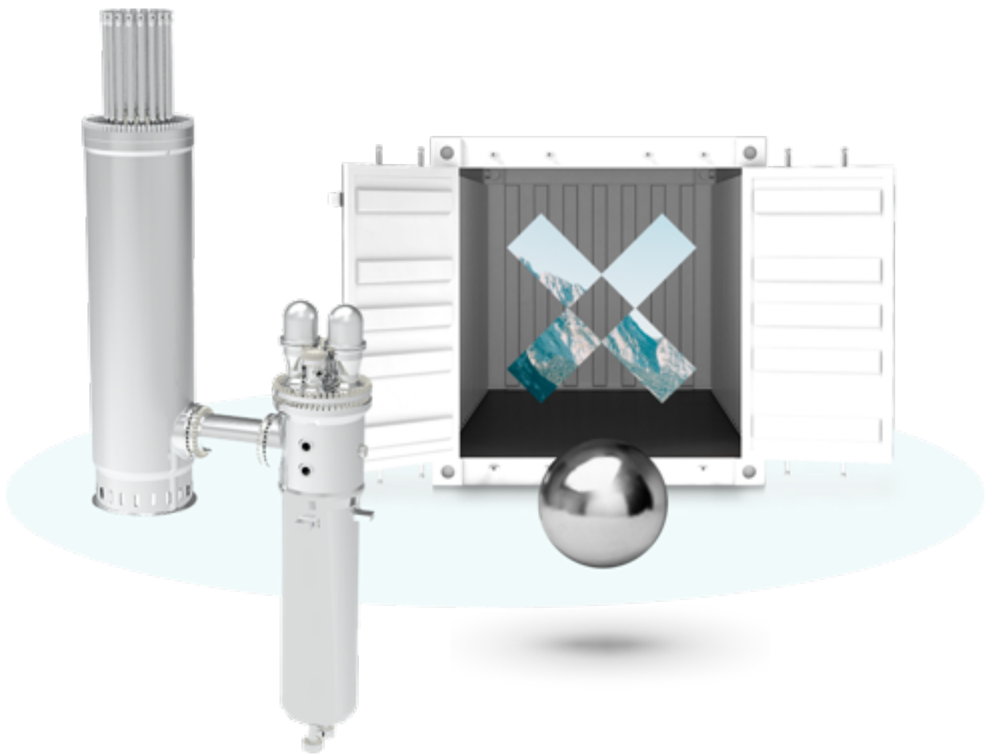
Intuitive Machines

- Began Intuitive Machines in 2016 to leverage NASA technologies for commercial space and terrestrial applications. Intuitive Machines won its first Commercial Lunar Lander Contract from NASA in 2018 with first landing scheduled for 2021.

Axiom Space

- Began Axiom Space in 2017 to develop the first commercial space station, to be launched by 2021.

We design & build reactors and the fuel that powers them



Reactor: Xe-100

We're focused on Gen-IV High-Temperature Gas-cooled Reactors (HTGR) as the technology of choice, with advantages in sustainability, economics, reliability and safety.

Reactor: Xe-Mobile

To address the need for ground, sea and air transportable small power production. We've developed reactor concepts with potential civilian government, remote community and critical infrastructure applications.

Fuel: TRISO-X

Our reactors use tri-structural isotropic (TRISO) particle fuel, developed and improved over 60 years. We manufacture our own proprietary version (TRISO-X) to ensure supply and quality control.

X-energy: Success Building On Success

AR ENERGY | About Us | REACTOR TECHNOLOGIES | INITIATIVES | INFORM/

Office of Nuclear Energy

U.S. Department of Energy Announces $160 Million in First Awards under Advanced Reactor Demonstration Program

OCTOBER 13, 2020

Home » U.S. Department of Energy Announces $160 Million in First Awards under Advanced Reactor Demonstration Program

WASHINGTON, D.C. – The U.S. Department of Energy (DOE) today announced it has selected two U.S.-based teams to receive $160 million in initial funding under the new Advanced Reactor Demonstration Program (ARDP). ARDP, announced in May, is designed to help domestic private industry demonstrate advanced nuclear reactors in the United States.

DOE is awarding TerraPower LLC (Bellevue, WA) and X-energy (Rockville, MD) $80 million each in initial funding to build two advanced nuclear reactors that can be operational within seven years. The awards are cost-shared partnerships with industry that will deliver two first-of-a-kind advanced reactors to be licensed for commercial operations. The Department will invest a total of $3.2 billion over seven years, subject to the availability of future appropriations, with our industry partners providing matching funds.

X-energy to work with Ontario Power Generation to advance clean energy technology in Canada

energy

NEWS PROVIDED BY
X-energy →
Oct 06, 2020, 15:38 ET

SHARE THIS ARTICLE

TORONTO, Oct. 6, 2020 /PRNewswire/ -- X-energy is pleased to work with Ontario Power Generation (OPG) to further advance the engineering and design work of the Xe-100 small modular reactor (SMR) technology for use in Canada.

wnn
world nuclear news

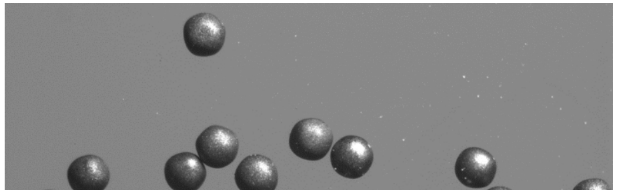
Energy & Environment | New Nuclear | Regulation & Safety | Nuclear Policies | Corporate | Uranium & Fuel | V

X-energy and NFI team up to supply HTGR fuel

30 June 2020

Share

US company X-energy has announced it is to be the exclusive counterparty to supply fuel to Japan's high-temperature gas-cooled reactor under a teaming arrangement with Nuclear Fuel Industries (NFI) of Japan.



IMMEDIATE RELEASE

DOD Awards Contracts for Development of a Mobile Microreactor

MARCH 9, 2020

The Department of Defense has awarded three teams, BWX Technologies, Inc., Lynchburg, Virginia; Westinghouse Government Services, Washington, D.C.; and X-energy, LLC, Greenbelt, Maryland; contracts to each begin design work on a mobile nuclear reactor prototype under a Strategic Capabilities Office initiative called Project Pele.

Key Attributes of Advanced Power Reactors

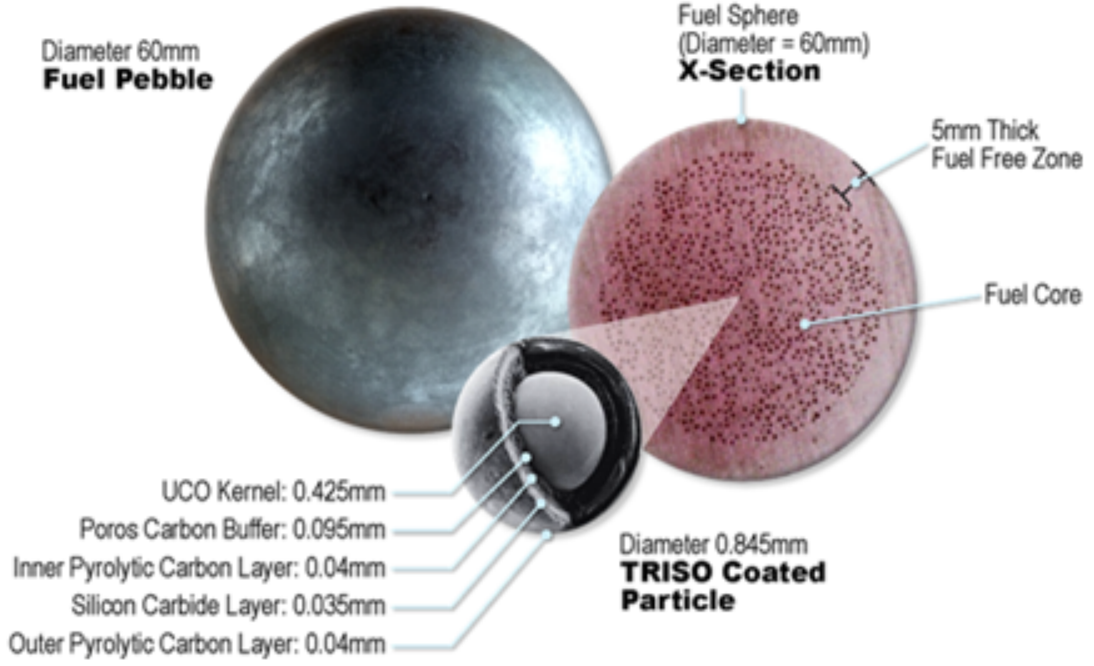
- **Inherently safe design**
  - Reactor reaches safe operating state without any operator intervention and can sustain in that state for an extended period.
- **Small exclusion zone**
  - Reactors can be located next to population centers with site boundaries of 100s of meters
- **Minimal radionuclide release even in beyond design basis events**
  - Mechanistic sources term design and analysis provides safety to members of the publics
- **Smaller road transportable, factory-made components without massive containment buildings**
  - Lower cost and faster construction time
- **Longer operating lifetime**
  - 60–80 years is desired

Reliable predictions of nuclear performance confirm safety and operating margins

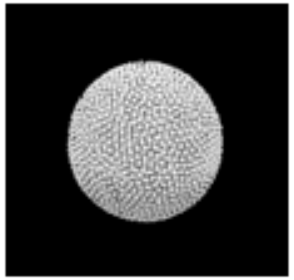
TRISO-X Fuel Production

TRISO Coated Particle Fuel is the Key to Safety

- Each TRISO particle forms a miniature containment vessel that retains radionuclides at the source for full spectrum of off-nominal events
- Demonstrated ability to withstand extremely high temperatures for extended periods (1800 °C for 300+ hours) without fuel failure
- High level of maturity due to >$250M investment by DOE in design and qualification and characterization of the TRISO fuel
- World's only active TRISO fuel fabrication facility.




Prototype pebble mold

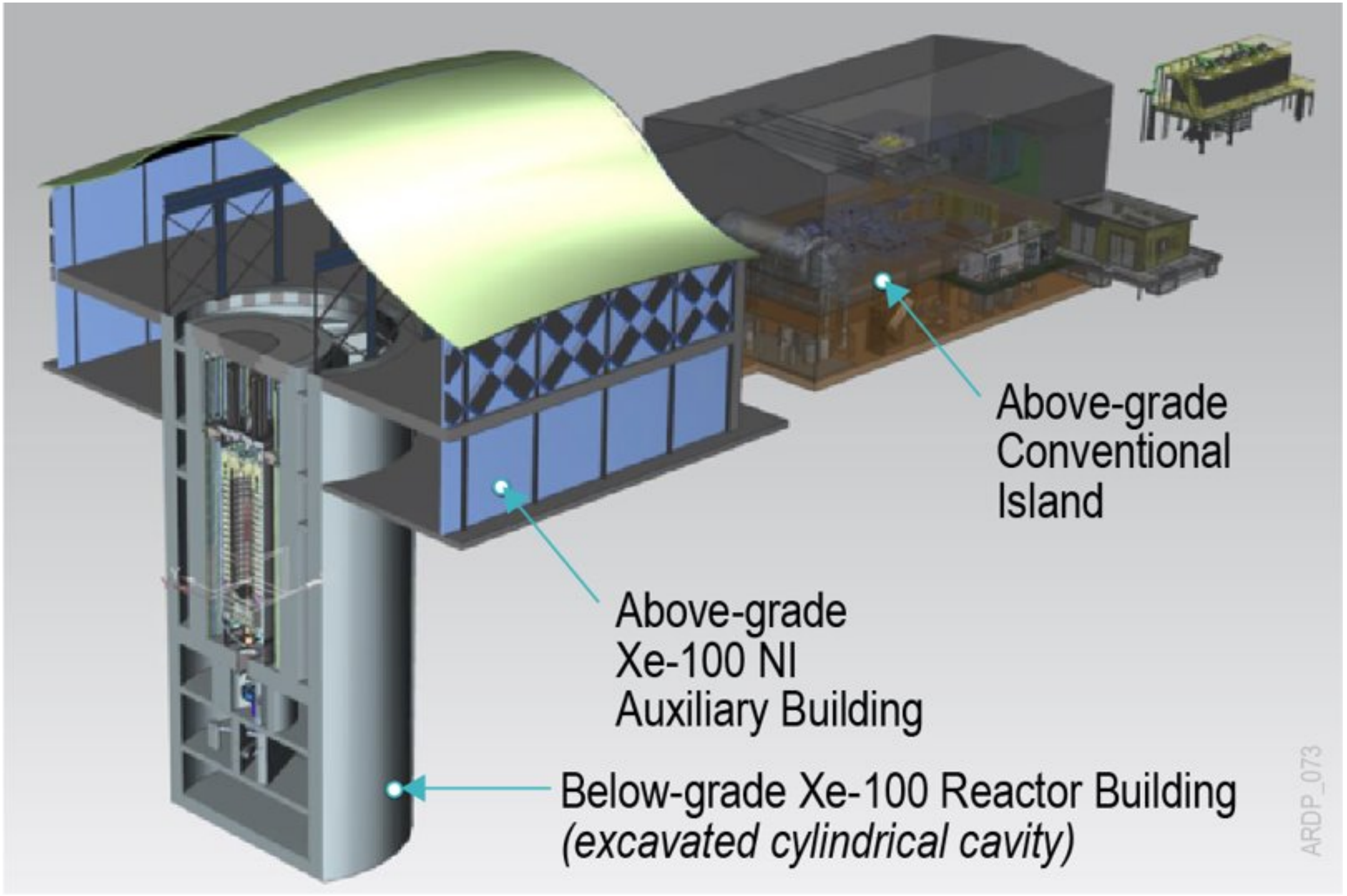

Innovative visualization of particles in pebble


First fuel form pebbles produced at ORNL, Fall 2018


DOE's Dr. Rita Baranwal tours TRISO-X Pilot Lab

Fuel is an integral part of the HTGR safety basis and economics

Xe-100 Unit Layout



Standard Technology Offering (4-Reactor Plant)

RB: Reactor Building
TB: Turbine Building
AB: Admin Building
HVY: High Voltage Yard
CR: Control Room
EB: Electrical Building
CT: Cooling Towers
HE-SFS: High Energy Spent Fuel Storage
ISFS: Intermediate Spent Fuel Storage
WS: Work Shop
CST: Condensate Storage Tanks
HeST: Helium storage
LW: Liquid waste
ST&IC: Stores and - Inventory Control
RW: Rad. Waste Building

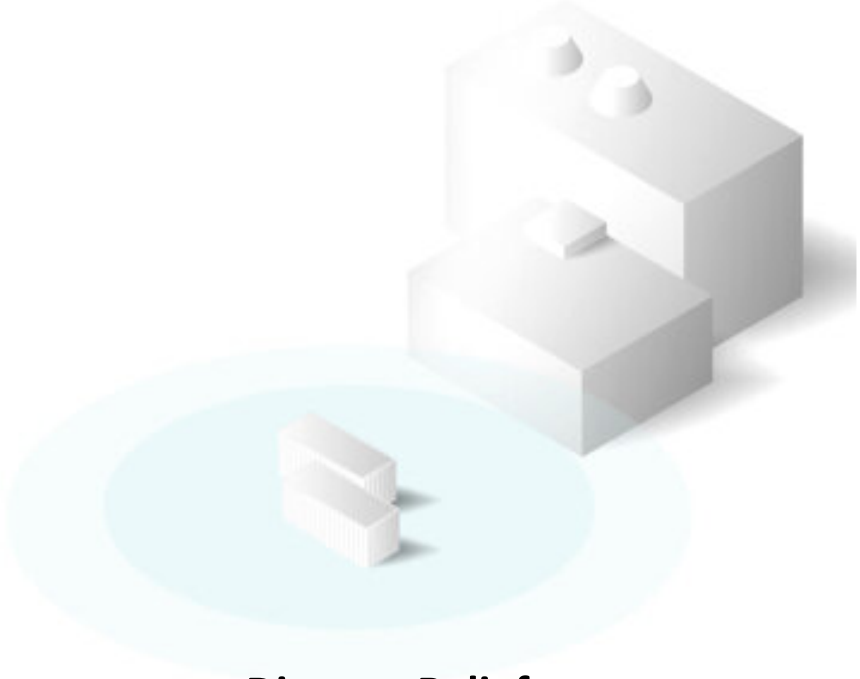
Standard power plant consists of four independent Reactor Modules (Reactor and Steam Generator)

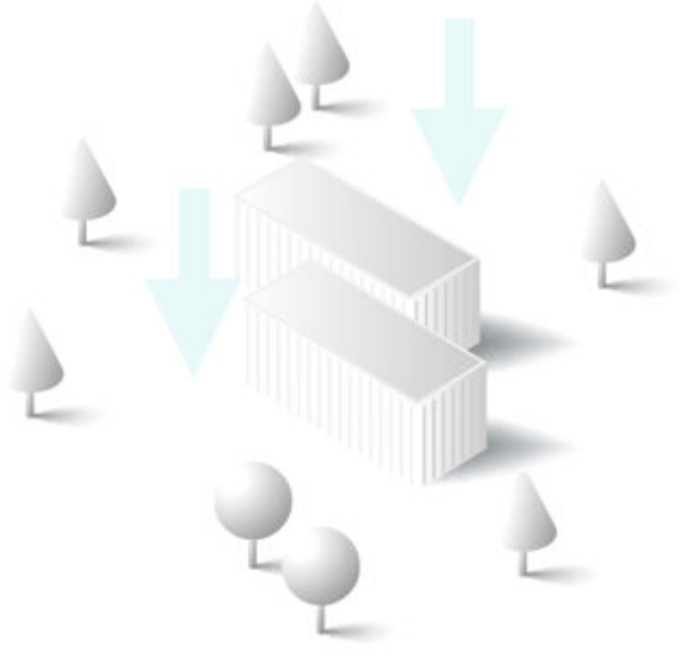
Each reactor module is connected to its own Steam Turbine/Generator

Single shared control room with only three operators

4 Units, 3 Licensed Operators, 1 Control Room

X-energy’s Novel Applications of Microreactors





Defense & forward bases

As the US Military prepares for “near-peer” adversaries of the future, highly portable power with a high energy density will be a game-changing technology.

Highly Portable Power

Disaster Relief

The ability to transport flexible electricity solutions that do not require fueling for months or years provides critical infrastructure to get railroads, water purification facilities, and hospitals powered again – within one week.

Be powered again – within one week

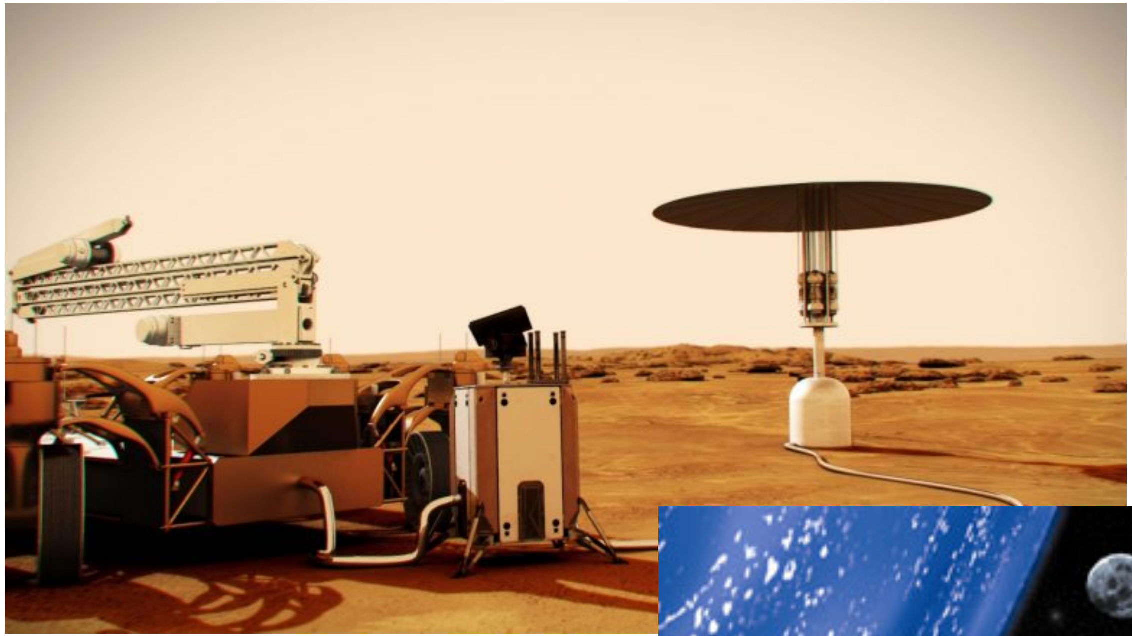
Remote Communities

Arid, Island and Alaskan/Canadian communities often use government-subsidized petroleum fuel deliveries to maintain their power. If their deliveries are disrupted, the impact can be significant.

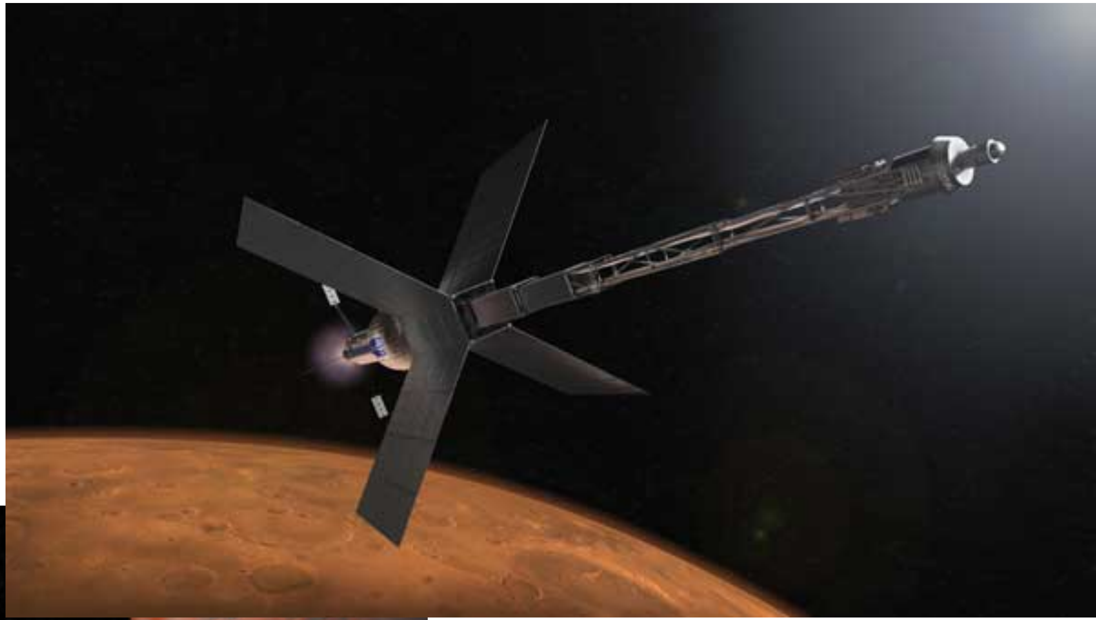
Maintain Power

Space Nuclear Applications

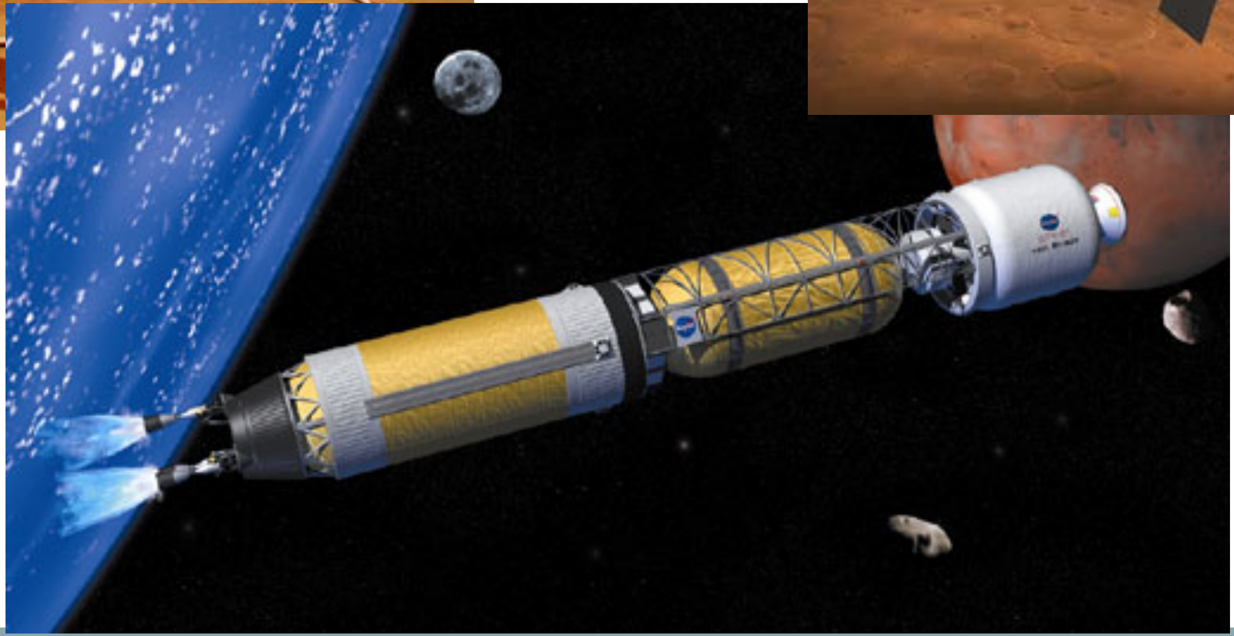
Fission Surface Power System



Nuclear Electric Propulsion

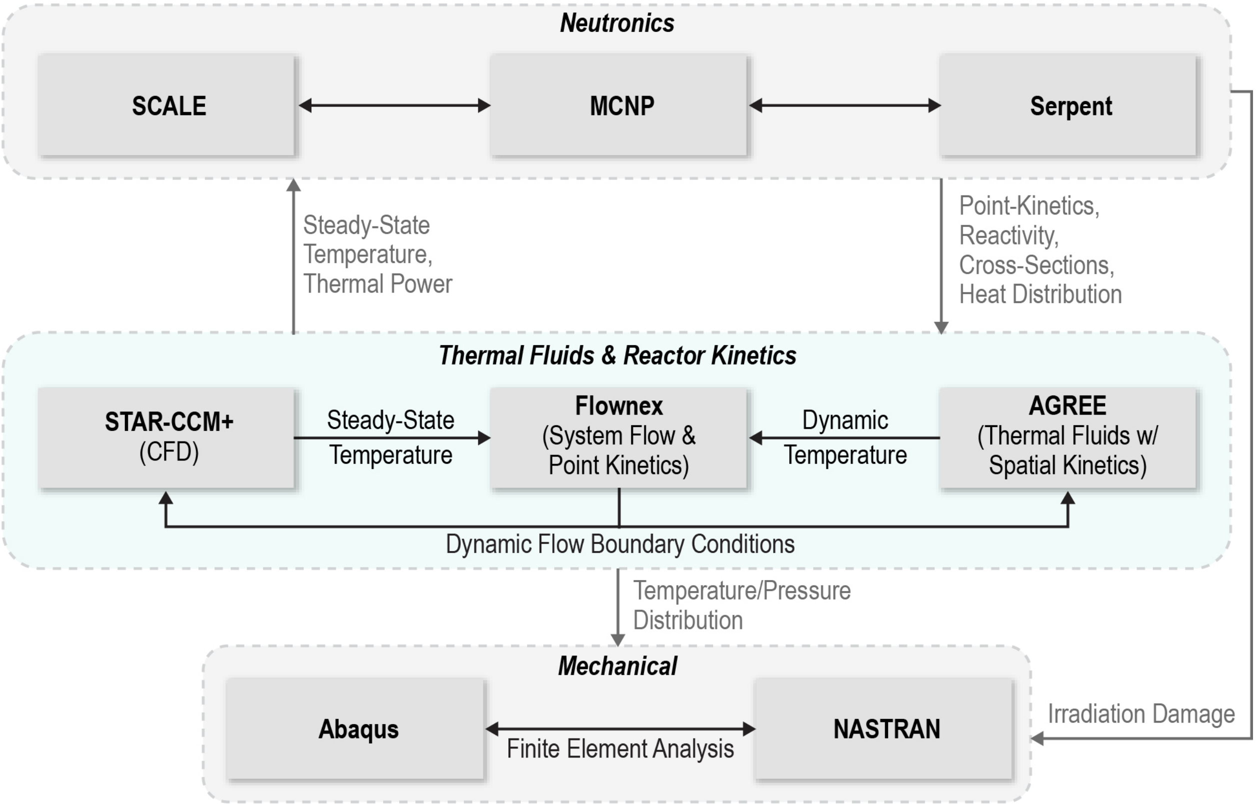


Nuclear Thermal Propulsion



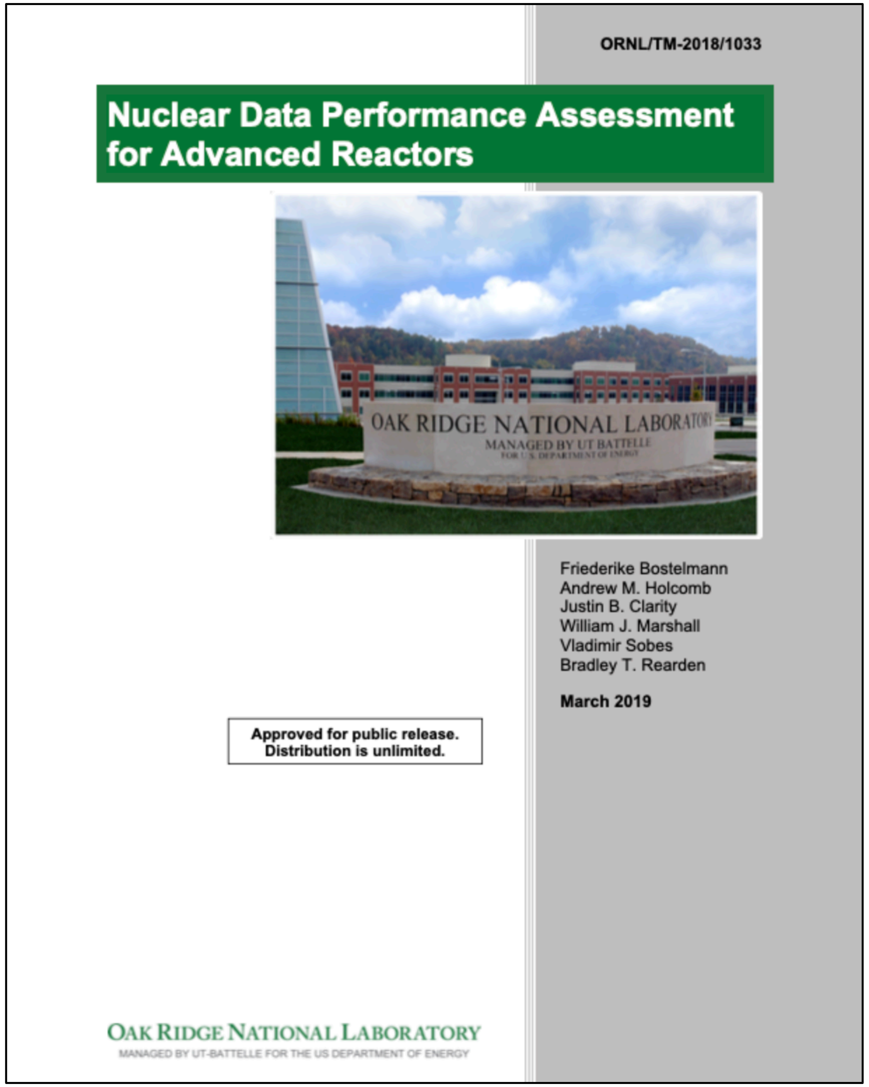
Images: NASA

Nuclear data provide a foundation for performance and safety analysis



Analysis	Tool/Model	Analysis Type	Outcome
Core neutronics	SCALE/ KENO/ORIGEN	Steady-state Monte Carlo neutron transport and transmutation	Power Profiles, Core life, Burnable poison design, Temperature and control element reactivity
Cross section generation	Serpent	Steady-state Monte Carlo neutron transport	Generated few-group cross sections for AGREE-Xe and verified reactivity results from SCALE and MCNP
Photon/Neutron Transport	MCNP	Steady-state Monte Carlo neutron and photon transport	Ex-core heating rates
Reactor Thermo-fluid Analysis	StarCCM+	High fidelity heat conduction and thermo-fluid dynamic behavior	Spatially resolved temperatures and coolant flow rates
Coupled neutronic-thermal fluid analysis	AGREE-Xe	Steady-state and time-dependent neutron diffusion/heat conduction/ subchannel fluid behavior	Peak and average temperatures of structures during transient scenarios
Plant Dynamics	Flownex	Steady-state and time-dependent analysis of plant-wide behavior	Plant/Reactor response to perturbations and fault conditions. Startup, shutdown, and critical power maneuvers
Shielding	SCALE/ MAVRIC/ ORIGEN	Steady-state neutron and gamma transport, activation, decay	Ex-vessel dose and activation rates
Structural Dynamics	NASTRAN	Dynamic Finite Element Analysis	Static-equivalent accelerations to be used for stress analysis, Load Isolation System evaluation
Mechanical and thermal stress	Abaqus	Steady-state Finite Element Analysis	FEA-calculated stresses, to be compared against material allowables to determine if the parts meet design requirements
Instrumentation & Controls	PSCAD	Simulation of electric power conversion	Power Balance of EPCS with a notional load bank at steady state response of system to various load transients, including abnormal loads and fault conditions
Hazards Analysis (Fire, chemical, mechanical, electrical, etc.)		Identification of hazards associated with assembly, transport, and disassembly operations	Design requirements for hazard mitigation systems (e.g., Fire Detection and Suppression)

Concerns with changes in ENDF/V-III.0 without consideration for reactor applications


ORNL/TM-2018/1033

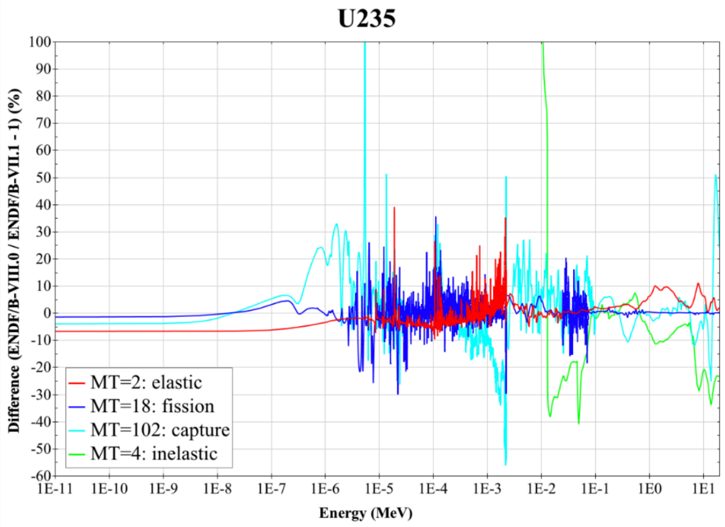
Nuclear Data Performance Assessment for Advanced Reactors

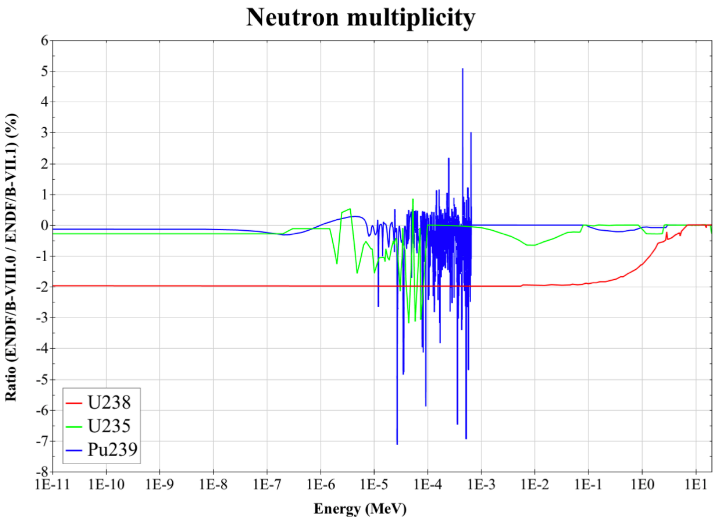
Friederike Bostelmann
Andrew M. Holcomb
Justin B. Clarity
William J. Marshall
Vladimir Sobes
Bradley T. Rearden

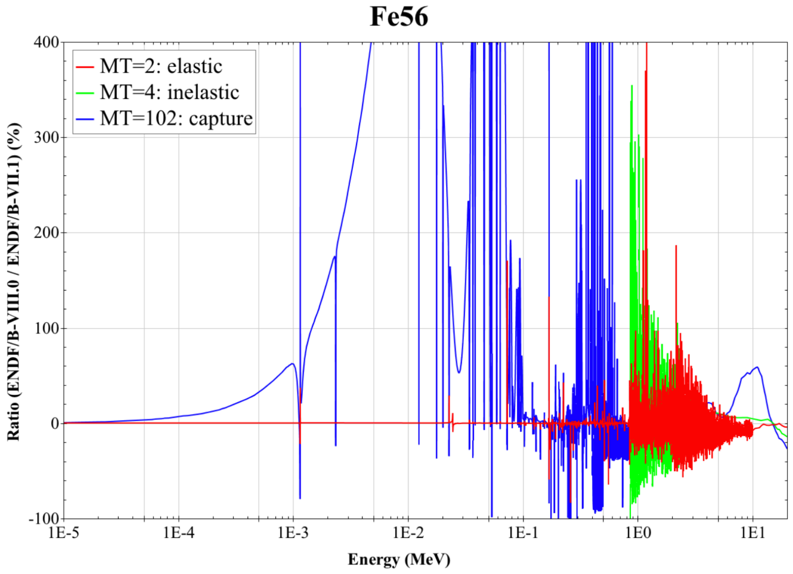
March 2019

Approved for public release.
Distribution is unlimited.

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







Needs for Validated Nuclear Data

- **Accurate reaction rates for every nuclide, not just integrated k_{eff}**
  - Power distribution
  - Reactivity control and shutdown margin
  - Doppler feedback
- **Fission product inventories, with accurate data for individual and cumulative yields**
  - Power and lifetime
  - Reactor kinetics
  - Xenon transients
  - Decay heat source terms for inherent safety confirmation
  - Radionuclide source terms for AOO, DBE, and BDBE analysis
  - Volatile radionuclide source terms for lift-off and plate analysis
- **Secondary radiation generation and deposition**
  - Prompt neutrons and gammas from fission
  - Gamma emissions from fission product decay
  - Neutron capture and gamma emission data
  - Material activation and decay
  - Neutron and gamma attenuation
  - Energy deposition in all materials
- **Thermal scattering law data**
  - Improved graphite data that could be used outside of ENDF/B-VIII.0
  - Advanced moderators/reflectors are needed for small HA-LEU cores
  - YH_x is of interest for lower temperature applications
  - NTP systems approach 3000 K for fuel and structural materials with H_2 as internal propellant
- **Irradiation damage assessment is needed for wide range of materials**
  - Damage cross sections are not available in ENDF libraries