Summary of Nuclear Data Needs for X-Energy Reactor Designs

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

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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.

• 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.

• 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.

• 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.

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

OCTOBER 13, 2020

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

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.

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-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.

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

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<td>Hazards Analysis</td>
<td></td>
<td>Identification of hazards associated with assembly, transport, and disassembly operations</td>
<td>Design requirements for hazard mitigation systems (e.g., Fire Detection and Suppression)</td>
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Concerns with changes in ENDF/V-III.0 without consideration for reactor applications
Needs for Validated Nuclear Data

• **Accurate reaction rates for every nuclide, not just integrated $k_{\text{eff}}$**
  - 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