

Office of Nuclear Energy Progress Updates on U.S. Small Modular Reactor Program Activities

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U.S. DEPARTMENT OF
ENERGY

Presidential and Departmental Priorities for Nuclear Energy

- President Trump ordered review of nuclear energy policy:

"[W]e will begin to revive and expand our nuclear energy sector... which produces clean, renewable and emissions-free energy. A complete review of U.S. nuclear energy policy will help us find new ways to revitalize this crucial energy resource."

- Development of advanced nuclear reactor and fuels technologies is critical to future of US nuclear sector

- White House National Security Strategy:

"We will improve America's technological edge in energy, including nuclear technology, next-generation nuclear reactors, better batteries, advanced computing, carbon-capture technologies, and opportunities at the energy-water nexus."

- Executive Order Promoting Energy Independence and Economic Growth

- Nuclear energy role as clean baseload power is key to environmental challenges:

"The Trump administration thinks nuclear power is very important. It's important domestically, it's important internationally"
Secretary Rick Perry in India April 2018

- Revive interest in and inform citizenry regarding nuclear energy's attributes

- Waste Policy: Restarting Yucca Mountain licensing proceedings and implementing a robust interim storage capability



Four Tracks of the U.S. Civil Nuclear Review

1

Preserve the existing fleet, with a focus on stopping premature shutdowns of reactors.

2

Restore U.S. nuclear R&D capabilities and enable innovation in new reactors.

3

Establish a plan to increase global market share.

4

Resolve uncertainty on waste, reprocessing, enrichment, medical isotopes.

DOE Office of Nuclear Energy Mission Priorities

Existing Fleet

**Advanced
Reactor
Pipeline**

**Fuel Cycle
Infrastructure**

Existing Nuclear Fleet

- Competitively-award joint, cost-shared research projects through **Light Water Reactor Sustainability** program to solve significant highest priority cost and technical problems threatening existing plants
- Fund primary and secondary candidate **Accident Tolerant Fuel** designs to enhance the number of candidate fuels for commercial reactor irradiations and accelerate commercial irradiations by 2 years from the 2022 Congressional mandate
- Conduct cyber research to develop intrusion-resistant systems and practices in support of US nuclear plants

Advanced Reactor Pipeline

- Execute an **Advanced Small Modular Reactor (SMR)** R&D program to promote competitive private-public partnerships to ensure SMRs commence powering the grid by 2026-2028.
- Deploy a **Versatile Advanced Test Reactor (VTR)** by 2026, to support accelerated development of advanced fuels and materials for U.S. advanced reactor vendors, as well as to provide the capability for testing of those fuels and materials to support licensing by the Nuclear Regulatory Commission.
- Complete development and qualification of **TRISO-coated particle fuel** by 2024 to provide the NRC and advanced reactor vendors with fuel performance data to support reactor licensing in the 2027-2035 time frame.
- Continue supporting the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to provide U.S. nuclear technology developers access to the technical, advanced computational, specialized R&D infrastructure and regulatory support required to deploy advanced nuclear reactors.

Fuel Cycle Infrastructure

- Re-establish civil uranium enrichment capability for high assay LEU in the U.S. by 2023.
- Outline a path forward to establish a U.S. reprocessing capability, including cost and schedule, with a goal of establishing the infrastructure/capability and options for advanced reprocessing in the 2025-2030 timeframe.
- Address the integrity and confidence of spent fuel management over the future decades through Used Nuclear Fuel Disposition (UNFD) R&D in areas of dry storage canister integrity, and transportation package performance.
- Ensure continued US university expertise and capabilities to support US public and private sectors through direct research, infrastructure support, graduate-level fellowships and undergraduate scholarships for students.

Nuclear Energy Research & Development Budget

	<i>FY 2017 Enacted</i>	<i>FY 2018 Omnibus</i>	<i>FY 2019 Request</i>
SMR Licensing Technical Support	95,000	-	0
STEP R&D	5,000	5,000	0
Reactor Concepts RD&D			
Advanced SMR R&D	-	-	54,000
<i>Light Water Reactor Sustainability</i>	40,000	47,000	20,000
<i>Advanced Reactor Technology</i>	87,000	155,000	74,000
<i>Versatile Advanced Test Reactor</i>	5,000	35,000	15,000
Reactor Concepts RD&D	132,000	237,000	163,000
Fuel Cycle Research and Development			
<i>MtIs Recovery and Waste Form Dvlpmnt</i>	33,400	30,000	5,000
<i>Advanced Fuels</i>	68,000	125,000	40,000
<i>Systems Analysis and Integration</i>	12,000	8,641	0
<i>MPACT (MtIs Prot'n, Accnt'g & Cntrl Techy)</i>	5,400	10,000	5,000
<i>UNFD R&D</i>	62,500	63,915	10,000
<i>Integrated Waste Management System</i>	22,500	22,500	0
<i>Fuel Resources</i>	3,700	-	0
Fuel Cycle R&D	207,500	260,056	60,000
Nuclear Energy Enabling Technologies			
<i>Modeling and Simulation Hub</i>	24,300	30,000	0
<i>Crosscutting Technology Development</i>	27,000	50,000	47,400
<i>NEAMS</i>	28,300	28,200	34,000
<i>Nuclear Science User Facilities</i>	35,500	50,800	34,600
Nuclear Energy Enabling Technologies	115,100	159,000	116,000

Nuclear Energy FY 2018 R&D Budget Highlights

**\$155M for Advanced Reactor Development,
including SMRs**

**\$35M for Versatile Advanced Test Reactor
R&D**

\$40M for Accident Tolerant Fuels

\$50M for Crosscutting competitive R&D

\$58M for Advanced Modeling & Simulation

Nuclear Energy FY 2019 R&D Budget Highlights

\$54M for Advanced SMR R&D

\$15M for Versatile Advanced Test Reactor R&D

\$40M for Accident Tolerant Fuels

\$47M for Crosscutting competitive R&D

\$34M for Advanced Modeling & Simulation

Nuclear Industry Funding Opportunity Announcement

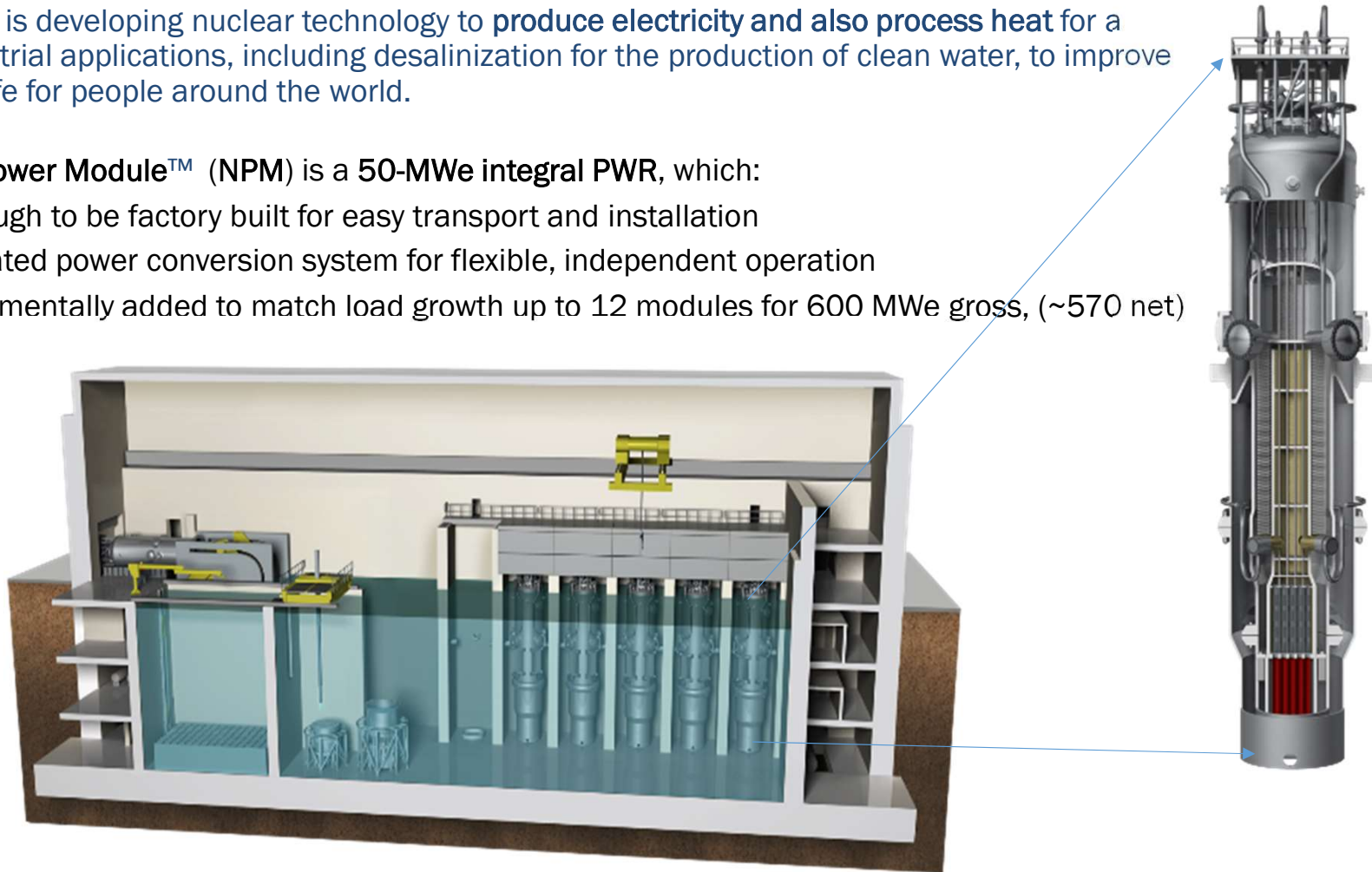
- New NE Support Vehicle for U.S. Nuclear Industry Initiatives
- Supports innovation and competitiveness of the industry by establishing private/public partnerships on cross-cutting applied research, development, and demonstration activities
- Three tiers of projects
 - FOAK Nuclear Demonstration Readiness projects – Mature technologies able to deploy in mid-to-late 2020's
 - Advanced Reactor Development projects – Technology development that will have an impact on safe, efficient and economic plant operations.
 - Regulatory Assistance grants – Supports resolution of regulatory/certification issues.
- Open for 5 years, quarterly reviews, maximum flexibility
- Supported by existing program funding
- Total of 22 proposals received during 1st Quarter of 1st Year
- About \$192 Million in DOE-funded work scope proposed
- 2nd Quarter proposal period ends April 30th
- Total FY 2018 funding available will be around \$110 Million

Progress in U.S. SMR Development

- SMR Licensing Technical Support Program has provided consistent financial support and risk reduction for domestic SMR vendors and customers since 2012
- Final year of funding in 2017
- Established Cooperative Agreements with U.S. technology vendors and utilities
 - B&W mPower (mothballed in 2016)
 - NuScale Power (more to come on this)
 - Tennessee Valley Authority (TVA)
 - Utah Associated Municipal Power Systems (UAMPS)
- Commissioned a number of studies focused on reducing technical and economic risk in SMR development

NuScale Power: Overview

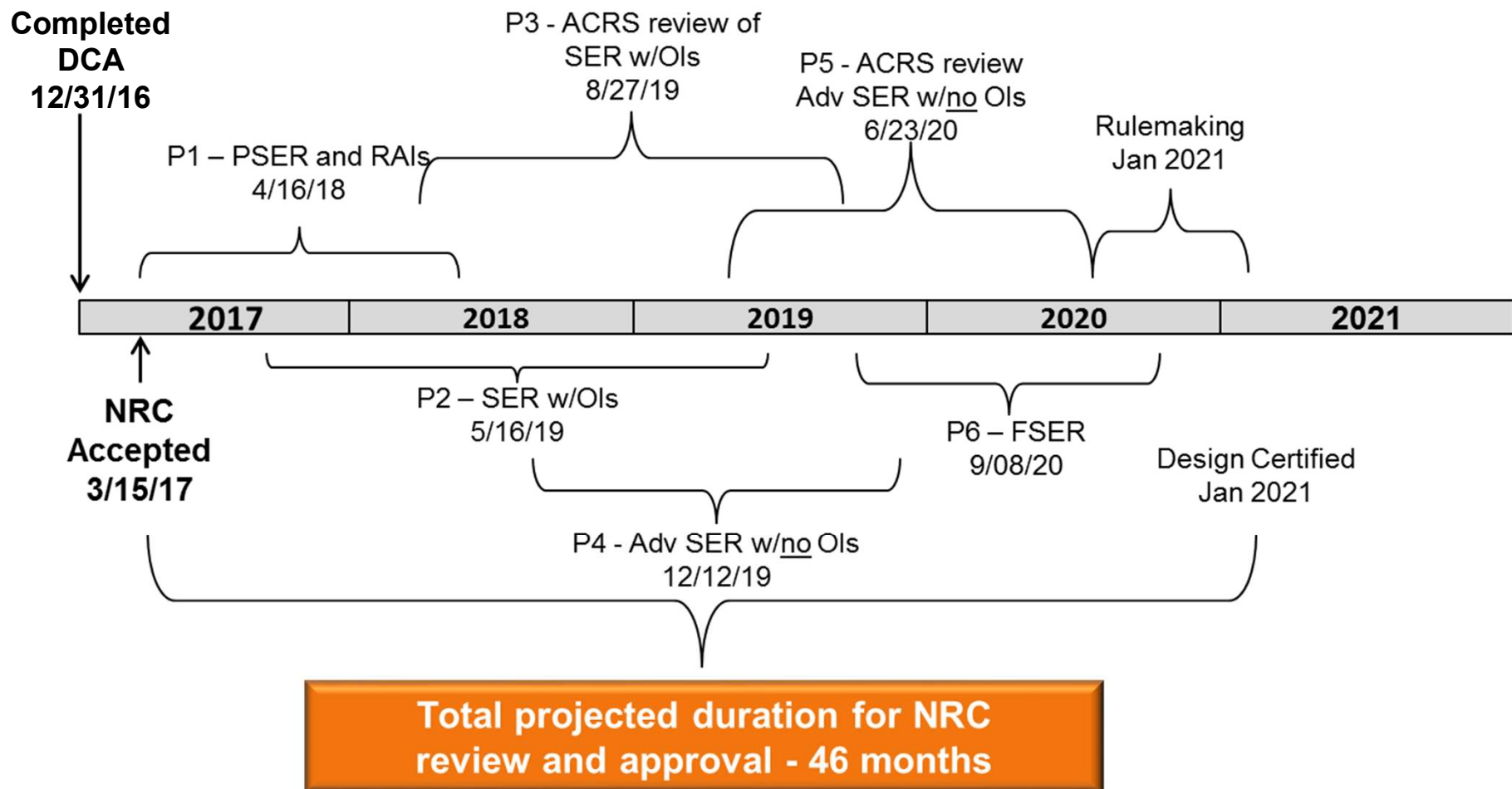
- NuScale Power is developing nuclear technology to **produce electricity and also process heat** for a variety of industrial applications, including desalinization for the production of clean water, to improve the quality of life for people around the world.
- The **NuScale Power Module™ (NPM)** is a **50-MWe integral PWR**, which:
 - is small enough to be factory built for easy transport and installation
 - has a dedicated power conversion system for flexible, independent operation
 - can be incrementally added to match load growth up to 12 modules for 600 MWe gross, (~570 net) total output



NuScale Power – Current Status

- NuScale submitted the first-ever Design Certification Application (DCA) for an SMR to the U.S. Nuclear Regulatory Commission (NRC) in December 2016
 - Docketed in March 2017 with design approval scheduled to complete in January 2021
 - Review is proceeding well, with the first phase completed on schedule in April 2018
 - NRC approved NuScale’s Licensing Topical Report that establishes the bases of how a design can be safe without reliance on any safety-related “class 1E” electrical power
- UAMPS - Carbon Free Power Project (CFPP) planned for first deployment in the U.S. of a NuScale Plant for commercial operation in 2026
 - Preferred location within the Idaho National Laboratory (INL) site
 - U.S. DOE awarded \$16 million in cost sharing to perform site selection, secure site and water, and prepare combined operating license application (COLA) to NRC
- NuScale continues to support the TVA Early Site Permit application associated with SMR deployment at the Clinch River Site in Tennessee.
 - TVA and UAMPS are currently negotiating the possibility of working together on “standard COLA content”

NuScale Baseline Design Certification Review Schedule



NuScale Power: Current Status (cont'd)

- NuScale Supply Chain:
 - NuScale is actively working towards selecting a major component fabrication partner.
 - Both domestic and international companies have expressed interest; final selection expected around mid-2018.
- International Opportunities:
 - In the United Kingdom, NuScale actively participating in the UK government's examination of SMRs, with current focus on impediments to investment in SMRs.
 - NuScale informed the Canadian Nuclear Safety Commission (CNSC) of intention to submit an application under the CNSC's pre-licensing vendor design review process.
 - NuScale is also exploring opportunities in Eastern Europe, Southeast Asia, Africa, and the Middle East.

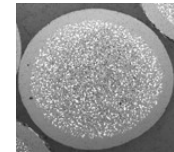
Overview of ARC15 Awards

- Congress directed an industry competition with lab partners in FY 2015
 - Funding provided by Congress in FY2015 to 2018
- Objective of awards: support two performance-based advanced reactor concepts for further development that:
 - Display significant advantages in the areas of safety, operations, and economics
- Two awards made July 2016
 - X-energy – Xe-100 Pebble Bed High Temperature Gas Reactor
 - Southern Co/ Terrapower – Molten Chloride Fast Reactor (MCFR)
- Award parameters
 - Cooperative Agreement, up to 5 years, up to \$80M total government funding
 - Minimum 20% industry cost-share (exceeded by both teams)

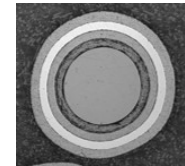
Xe-100 Pebble Bed High Temperature Gas Reactor

- **Main Focus** - Further Xe-100 design, establish U.S. fuel manufacturing capability, address regulatory issues
- **Project Cost** - \$53M, 25% cost-share (\$40M from DOE / \$13M from private sector)
- **Partners** - BWXT, Teledyne Brown, SGL Group, ORNL, INL, and Oregon State University
- **BP1 key accomplishments**
 - Fabricated kernels, TRISO particles, and the first Xe pebble
 - Established advanced fuel characterization techniques
 - Completed white papers on regulatory issues
 - Developed unique mechanistic source term codes
- **BP2 planned accomplishments**
 - Scale up fuel fabrication processes and move from surrogate material to depleted and natural uranium
 - Develop graphite lifetime predictive models and heat transfer model
 - Complete white papers for submission to NRC
 - Perform engineering analyses of selected plant systems / operations

*Uranium Oxycarbide
Kernel Fabrication*



*Surrogate TRISO
Particle Production*



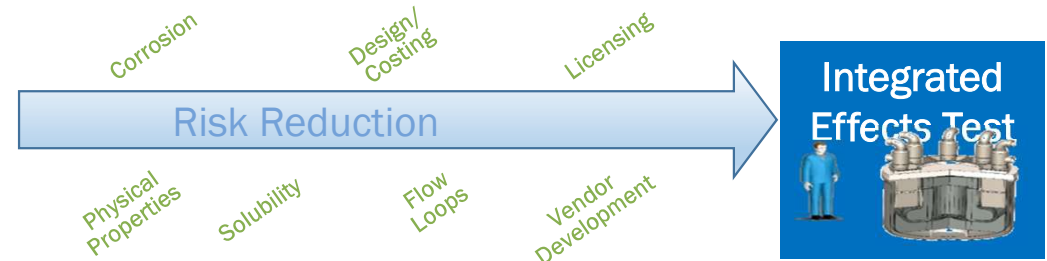
First X-energy Pebble (Fall 2016)



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Molten Chloride Fast Reactor (MCFR)

- **Main Focus** – Study salt properties, develop corrosion resistant materials, testing to reduce technical and licensing risks
- **Project Cost**– \$68 M, 41% cost-share (\$40M from DOE / \$28M from private sector)
- **Partners** - TerraPower, ORNL, EPRI, and Vanderbilt University
- **BP1 Key Accomplishments**
 - Investigated salt properties (density, specific heat, viscosity, etc.)
 - Developed conceptual design of the Integrated Effects Test (IET)
 - Completed test reactor conceptual design and safeguards and security approach
 - Active engagement with NRC
- **BP2 Planned Accomplishments**
 - Complete design for the IET facility
 - Measure primary fuel salt properties
 - Demonstrate corrosion resistant components can be fabricated / joined
 - Identify regulatory framework needs to support licensing



Questions?