Overview of Advanced Reactor and Advanced Manufacturing Program Activities

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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 proceeding and implementing a robust interim storage capability
DOE Office of Nuclear Energy Mission Priorities

Existing Fleet

Advanced Reactor Pipeline

Fuel Cycle Infrastructure
Existing Nuclear Fleet

• Develop primary and secondary candidate Accident Tolerant Fuel designs to enhance the number of candidate fuels for commercial reactor irradiations

• Accelerate commercial irradiations which support advanced fuel designs by 2 years from the 2022 congressional goal

• Continue R&D activities under the Light Water Reactor Sustainability program to solve significant highest priority cost and technical problems threatening existing fleet lifetime extension
Fuel Cycle Infrastructure

• 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.

• Recycle spent Naval Reactor fuel to produce the High Assay Low Enriched Uranium needed for advanced reactors.

• Increasing U.S. Government recycling activities and capabilities may provide potential options for the long-term management of used nuclear fuel.

• 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.
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.
Advanced Reactor Pipeline Supply Chain Focus Areas

- Production line suppliers vs low volume suppliers
- Maintain Standardization (GD&T windows, interfaces)
- Design for Manufacturing, Assembly, Transport
  - Iterative Design (listening to suppliers)
  - Component prototyping
- Sustaining a long term supply chain
- Uniquely positioned to take advantage of advanced manufacturing techniques (shop based fab)
Advanced Reactor Pipeline Supply Chain Focus Areas (cont)

• Protection of Intellectual Property

• Selecting suppliers willing to adapt

• Selecting suppliers with nuclear safety culture

• Understanding supply chain development schedules

• Transitioning to a purpose built factory
Advanced Small Modular Reactor R&D program

• New Advanced Reactor Pipeline program for FY19

• Support cost-shared early-stage design-related technical assistance and R&D for advanced SMR designs

• 1 year, cost-shared funding, nominally 50 percent private-public

• More specifically, would allow activities such as:
  • Thermal-hydraulic testing and analysis supporting reactor coolant system designs;
  • Seismic analyses to inform generic SMR plant structural design
  • Emergency core cooling system and component research;
  • Design and development of early-stage prototype components;
  • Supply chain development and decisions on specific suppliers;
  • Simulator development and reactor operator training; and,
  • Procurement of long lead items such as reactor pressure vessels, containment vessels, steam generators, and other complex SMR components
Advanced Reactor Pipeline: Supplying Components

Advanced Methods for Manufacturing (AMM)

• Advanced manufacturing techniques can help reduce cost and time to make quality nuclear components

• Size, number, complexity, and material will drive which advanced methods is used – AM or PM-HIP

• Existing Nuclear industry very interested in additive manufacturing:
  1. Produce replacement parts for the existing fleet with a very short turn around - Obsolete parts—remember some units are over 40 years old;
  2. Produce new or complex parts for the new fleet of ALWRs, SMRs and Gen IV applications;
  3. Improved designs to include flow characteristics and special features not available through casting, forging or machining;
  4. Favorable material properties can be manufactured providing unique microstructures

• Acceptance criteria, qualification requirements and inspection methods need to be developed/accepted by standards organizations (ASME, ASTM) and NRC.
AMM Program Vision and Goals

- **Vision**
  - To improve the methods by which nuclear equipment, components, and plants are manufactured, fabricated, and assembled by utilizing practices found in industries such as oil, aircraft, and shipbuilding

- **Goal**
  - To reduce cost and schedule for new nuclear plant construction
  - To make fabrication of nuclear power plant (NPP) components faster, cheaper and more reliable
Additive Manufacturing Processes

- Powdered Metal – Hot Isostatic Pressing

- Additive Manufacturing:
  - Powder Bed Laser Sinter
  - Laser Free Form Wire Fed
  - E-Beam Wire Fed
  - E-Beam Powder Bed
  - Powder Bed Binder Jet

- Surface Coating/Cladding processes
  - Plasma Nitriding
  - Friction Stir AM
  - Powder Spray
Additive Manufacturing

AM is Not a Single Process

A partial list of metal AM technologies

- Powder Bed Fusion (PBF)
- Direct Metal Laser Sintering (DMLS)
- 3-D Printing
- Laser Freeform Manufacturing Technology (LFMT)
- Wire + Arc AM (WAAM)
- Electron Beam Melting (EBM)
- Selective Laser Melting (SLM)
- Additive Layer Manufacturing (ALM)
- Rapid Plasma Deposition (RPD)
- Laser Cladding Technology (LCT)
- Directed Energy Deposition (DED)
- Laser Engineered Net Shaping (LENS)
- Laser Deposition Technology (LDT)
- Ultrasonic Additive Manufacturing (UAM)

Diversity of AM Processes – By Source of Energy & Material
Current AMM Focus Areas

- **Factory and Field Fabrication Techniques**
  - High speed, high quality welding technologies

- **Assembly and Material Innovation to Enhance Modular Building Techniques**
  - Advances and innovation in high strength concrete and rebar

- **Advances in Manufacturing Processes**
  - Powdered Metal/Hot Isostatic Pressing
  - Additive manufacturing
  - Cladding and surface modification methods

- **Improved Concrete Inspection, Acceptance and Construction Methods**
  - Improved methods to facilitate the curing of concrete

- **Data Configuration Management**
  - Imaging techniques for as-built design
Representative model of NuScale Power Reactor Vessel

Innovative Manufacturing Process for Nuclear Power Plant Components via Powder Metallurgy and Hot Isostatic Pressing Methods

SMR Reactor Pressure Vessel Manufacturing & Fabrication Technology Development – FY 2017

- Goal is to produce a code acceptable SMR Reactor Pressure Vessel (RPV) within 12 months
- Manufacture the major components for a 2/3 scale (44’ long x 6’ in diameter) of a NuScale RPV utilizing:
  - Powder Metallurgy/ Hot Isostatic Pressing (PM/HIP)
  - Electron Beam Welding
  - Diode Laser Cladding
  - Cryogenic Machining
SMR Vessel Head Manufacture

Hot Degassing of Powder Filled Upper Head

Following Degassing, All Fill Stems are Crimped and Welded Shut. Now Ready for HIP

After HIP Consolidation
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 Module Design

Overview

- 50 MWe per unit/module – up to 12 units/plant
- Utilizes standard UO2 LWR fuel
- 2.5 year refueling interval
- Utilizes passive circulation cooling under normal operating conditions
- Design features entire containment vessel submerged in reactor pool for improved safety
- Long-term passive cooling capability extends time required for operator intervention
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 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 NuScale 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.
NuScale Supply Chain Issues

• The capability and capacity to fabricate large ASME Section 3 pressure vessels no longer exists in the US. There are a few companies that probably have the capability to build a few NuScale SMRs, but capacity would have to be expanded to support manufacturing in any significant quantities.

• The primary issue for NuScale is creating the production scale capacity necessary to satisfy the expected demand for modules.

• While the vast majority of the NuScale SMR forgings can be made domestically, a few of the larger forgings will require investment in US large forging capability.

• The US has alloy 690 tube manufacturing capability, but to accommodate the additional length of the NuScale helical steam generator, the capacity must be enhanced.

• NuScale is using ASME code approved materials
Questions?

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