Agenda

- DOE SMR Licensing Technical Support Program
- NuScale Technology Overview
- How Do We Know It Works?
- The Safety Case
- Commercialization Plan
- Q and A
Brief NuScale History

- NuScale first of current US SMRs to begin design of commercial NPP.
- NuScale technology in development and design since 2000 (DOE) MASLWR program, with INL, lessons from AP600/1000 ¼-scale testing facility built and operational
- Electrically-heated 1/3-scale Integral test facility first operational in 2003
- Began NRC design certification (DC) pre-application project in April 2008, >20K Mhrs
- Acquired by Fluor in October 2011
- ~400 people currently on project, ~$500MM spent project life-to-date ($12MM/mo)
- >350 patents pending/granted, 19 countries
- Portland, Corvallis, Rockville, Charlotte, Richland, London
- US DOE SMR Awardee, 12/12/13, $217MM
U.S. Department of Energy’s Perspective on Small Modular Reactors

Ray Furstenau
Office of Nuclear Energy
U.S. Department of Energy

September 13, 2016
Why SMRs?

1. A New Standard of Passive Nuclear Safety
   • Plants that can safely shutdown without operator interaction, off-site power or off-site water and remain so indefinitely

2. Greater Affordability
   • Easier financing for public power entities in the U.S. and smaller countries
   • Factory fabrication, shorter construction times

3. Energy and Environmental Benefits
   • Greenhouse gas and air pollution avoided
   • Grid benefits: stability, security, quality, availability, reliability, etc...
   • Coal plant replacement
   • Energy output more appropriate for countries with smaller electrical grids
   • Hybrid energy systems and flexible integration with renewables

4. Importance to National Security
   • Retaining influence in the nuclear nonproliferation regime through innovative nuclear products that are attractive to other countries

5. Manufacturing jobs and supply chain opportunities in the United States

“I believe small modular reactors could represent the next generation of nuclear energy technology, providing a strong opportunity for America to lead this emerging global industry.”

-- Secretary Moniz, 2013
DOE SMR Program

- SMR Licensing Technical Support (LTS) program initiated in FY12
- “Small” = reactor modules with individual outputs less than 300 MWe
- “Modular” = factory fabrication of modules + multiple modules at each plant site
- DOE SMR LTS Mission: Promote the accelerated deployment of SMRs by supporting design certification and licensing for U.S.-based SMR projects through cost-shared cooperative agreements with industry partners
- Designed as a 6 year, $452M program

“All-of-the above is not merely a slogan, but a clear-cut pathway to creating jobs and ... reducing carbon emissions. President Obama has made clear that he sees nuclear energy as part of America’s low carbon energy portfolio.” – Secretary Moniz, 2014
Partnership with NuScale Power

- NuScale has been meeting the milestones established in the cooperative agreement with the Department.
- NuScale has been diligently engaging with the NRC to assure the design certification application will be of high quality.
Partnerships with Utilities to Site SMRs

- Demonstrating SMR-specific site licensing methodologies and processes is important for developing the commercialization potential of SMR technologies
- DOE entered into cost-shared agreements with 2 industry partners

**FY2015 Congressional Appropriation language:**

“Prior funds shall be available for the site permitting and related licensing activities to support the continued development of small modular reactor technologies previously selected under this program.”

<table>
<thead>
<tr>
<th>Partner</th>
<th>Expected outcome</th>
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<tbody>
<tr>
<td>Tennessee Valley Authority (TVA)</td>
<td>Early Site Permit Application and Combined Construction and Operating License Application (COLA) for an SMR at TVA’s Clinch River Site</td>
</tr>
<tr>
<td>NuScale and Utah Associated Municipal Power Systems (UAMPS)</td>
<td>Documentation leading to UAMPS COLA for an SMR in Idaho</td>
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DOE Workshop – *The Path to SMR Commercialization*

- June 2016 workshop solicited industry input on possible future direction for DOE SMR efforts
- Workshop report to be completed in late September or early October
- Options suggested at the workshop to aid SMR development and deployment:
  - DOE cost-shared support for design finalization and licensing efforts
  - Financial incentives, including tax credits, for SMR deployment
  - R&D on advanced manufacturing technologies
  - Establish a Center of Excellence for advanced nuclear manufacturing
  - Hybrid energy system demonstration
  - Design and construct an SMR-powered microgrid
  - Federal power purchase agreements for SMR projects
Power purchase agreements from federal facilities

• DOE is investigating power purchase agreement options for federal facilities to purchase SMR power, including from the UAMPS CFPP
• An SMR power purchase agreement from a federal facility would:
  • Avoid the social costs of carbon emissions and address clean energy targets for federal facilities as defined in Executive Order 13693
  • Add to electricity reliability/security for nearby federal facilities
• An SMR power purchase agreement could:
  • Include additional reliability requirements for mission-critical applications
  • Include additional provisions to reduce vulnerability to intentional destructive acts or natural phenomena
Concluding Thoughts

- The SMR program is one of the highest priorities in the U.S. Department of Energy
- The Department is pleased with the progress made to date on the development of the NuScale SMR design and the UAMPS CFPP
- The Department is considering future program investments and actions that will further enhance the commercialization potential of SMRs
What is a NuScale Power Module?

- A NuScale Power Module (NPM) includes the reactor vessel, steam generators, pressurizer and containment in an integral package that eliminates reactor coolant pumps and large bore piping (no LB-LOCA)
- Each NPM is 50 MWe and factory built for easy transport and installation
- Each NPM has its own skid-mounted steam turbine-generator and condenser
- Each NPM is installed below-grade in a seismically robust, steel-lined, concrete pool
- NPMs can be incrementally added to match load growth - up to 12 NPMs for 600 MWe gross (~570 net) total output
NuScale Technology Overview
Comparison size envelope of new nuclear plants currently under construction in the United States

126 NuScale Power Modules

NuScale’s combined containment vessel and reactor system

*Source: NRC*
**Coolant Flow Driven By Physics**

*Convection* – energy from the nuclear reaction heats the primary reactor coolant causing it to rise by convection and natural buoyancy through the riser, much like a chimney effect.

*Conduction* – heat is transferred through the walls of the tubes in the steam generator, heating the water (secondary coolant) inside them to turn it to steam. Primary water cools.

*Gravity* – colder (denser) primary coolant “falls” to bottom of reactor pressure vessel, cycle continues.
How Do We Know It Works?
NuScale Reactor Qualification Test Plan outlines Design Certification and First Of A Kind Engineering (FOAKE) projects for reactor safety code development, validation, reactor design and technology maturation to reduce First Of A Kind (FOAK) design risk.
Full Length SG Test (TF-2) Construction/Hardware
NuScale RPV Head Ingot Being Forged

- 150 inches diameter
- 30 inches high
- 142,000 pounds

Images Provided courtesy of Sheffield Forgemasters International Ltd
Machining of the NuScale RPV Head

Images provided courtesy of Sheffield Forgemasters International Ltd
President Jimmy Carter briefed by James R. Floyd, supervisor of TMI-2 operations, with Harold R. Denton, director of the Office of Nuclear Reactor Regulation in the Nuclear Regulatory Commission. This control room design was complete in the late 1960s, before construction began in 1970.

In this April 29, 2015 photo, Chris Dujado, left, and Billy Horton, right, control room operators for Unit 2, review information from monitoring panels at the Watts Bar Nuclear Plant near Spring City, Tenn. The control room design is strikingly similar to those of the 1960s, despite innovations behind the panels. (AP Photo/Mark Zaleski)
The NuScale Power simulator control room design brings together decades of Digital I&C, Human Factors Engineering and Human Systems Interface research and field experience.

At a recent NuScale Family day, 10-year-old Sam Shore felt completely at home in the NuScale Control Room Simulator.
NuScale Control Room Simulator
The Safety Case
Core Damage Frequency Significantly Reduced

Source: NRC White Paper, D. Dube; basis for discussion at 2/18/09 public meeting on implementation of risk matrices for new nuclear reactors
More Barriers Between Fuel & Environment

Conventional Designs
1. Fuel Pellet and Cladding
2. Reactor Vessel
3. Containment

NuScale’s Additional Barriers
4. Water in Reactor Pool
5. Stainless Steel Lined Concrete Reactor Pool
6. Biological Shield Covers Each Reactor
7. Reactor Building
Smaller Emergency Planning Zone (EPZ) Due to Safer Design

Traditional PWR

Site Boundary EPZ

- Passive Safety
- Additional Fission Product Barriers
- Significant Delay in Release of Radiation
Innovative Advancements to Reactor Safety

Nuclear fuel cooled indefinitely without AC or DC power*

WATER COOLING  BOILING  AIR COOLING

No Pumps • No External Power • No External Water

Decay heat removed by steam generators and DHRS (3 Days)
Decay heat removed by containment (30 Days)
Transition to long-term air cooling (> 30 Days)

• 30 days is a minimum based on very conservative estimates.

*Alternate 1E power system design eliminates the need for 1E qualified batteries to perform ESFAS protective functions – Patent Pending
Commercialization Plan
SMR Market Potential

- UK NNL* calculated the potential SMR market to be approximately 65-85GW by 2035, 55-75 GW excluding Russia

- This is equivalent to 1100 – 1500 NuScale Power Modules (NPMs)
- At 25% market share, and 10 year deployment timeframe, 28–38 NPM / year
- At 36 NPM / year, approximately 1000 workers dedicated to machining, assembling and testing NPMs

*UK National Nuclear Laboratory “SMR Feasibility Study”, December 2014
NuScale Advisory Board (NuAB)
Site Overview

34.5 acres (~14 hectares) within the protected area fence
Program WIN (Western Initiative for Nuclear)

- Western Initiative for Nuclear (WIN) is a multi-western state collaboration to deploy a series of NuScale Power Projects.
- Involved Program WIN participants: NuScale, UAMPS, Energy Northwest, ID, UT, OR, WA, WY, AZ, NM, MT?
NuScale Diverse Energy Platform (NuDEP) Initiative

- SAFE
- SMALL
- SCALABLE
- FLEXIBLE
- RELIABLE
NuScale includes unique capabilities for following electric load requirements as they vary with customer demand and rapid output variations from renewables: NuFollow™

There are three means to change power output from a NuScale facility:

- **Dispatchable modules** – taking one or more reactors offline for extended periods of low grid demand or sustained wind output
- **Power Maneuverability** – adjusting reactor power for one or more modules (intermediate time frames)
- **Turbine Bypass** – bypassing turbine steam to the condenser (short time frames)

Explored integration with Horse Butte wind farm in Idaho

Partnered with Utah Associated Municipal Power Systems and Energy Northwest
Horse Butte Wind Farm

- Commissioned in 2012
- 32 Vestas V100 turbines
- 1.8 MWe capacity per turbine
- 57.6 MWe total capacity
- 17,600 acres

24 hour output (Nov. 11, 2014)
Target Output for NuScale Module

Power (MWe)

Typical electrical demand

NuScale Output (target)

Horse Butte Output

4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
### Overall EPC Overnight Plant Costs ($1,000,000)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>2014 Dollars</th>
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<tbody>
<tr>
<td>Power Modules (FOAK Cost plus Fee, Transportation, &amp; Site Assembly)</td>
<td>$ 848</td>
</tr>
<tr>
<td>Home Office Engineering and Support</td>
<td>$ 144</td>
</tr>
<tr>
<td>Site Infrastructure</td>
<td>$ 60</td>
</tr>
<tr>
<td>Nuclear Island (RXB, RWB, MCR)</td>
<td>$ 538</td>
</tr>
<tr>
<td>Turbine Island (2 buildings with 6 turbines each)</td>
<td>$ 350</td>
</tr>
<tr>
<td>Balance of Plant (annex, cooling towers, etc)</td>
<td>$ 225</td>
</tr>
<tr>
<td>Distributables (Temp. Bldgs., Field Staff, Const. Equip., etc.)</td>
<td>$ 545</td>
</tr>
<tr>
<td>Other Costs</td>
<td>$ 185</td>
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**Total Overnight Price**  
$ 2,895

$ 5,078 per kWe net

Note: Delivered costs shown are in 2014 $’s.
NuEx Tours – NIST, Control Room Simulator and UMM
The Element of Nu