Via: Email

August 6, 2020

ATTN: Nate Hardy, UAMPS CFPP Project Manager

SUBJECT: Responses to UAMPS CFPP Town Hall Questions about NuScale SMR Technology

Dear Nate:

This letter is in response to the questions brought up during the July 21st Town Hall hosted by the Utah Associated Municipal Power Systems (UAMPS) regarding its Carbon Free Power Project. Please see the responses provided by NuScale Power to questions on NuScale's technology in the sections that follow.

Question: *Have you ever tested a full scale or other prototype of the reactor core and primary cooling system using nuclear fuel as the power source?*

Response:

NuScale designed and built the state-of-the-art NuScale Integral System Test (NIST-2) facility located at Oregon State University in Corvallis, Oregon. The exclusive access NIST-2 facility provides NuScale with a tremendous advantage for modular prototype testing. It holds a one-third scale prototype that replicates the entire NuScale Power Module™ (NPM) and reactor building cooling pool. The facility has demonstrated the strong safety case and viability of the NPM and provides an enhanced representation of NuScale's small modular reactor design, which operates using the principles of buoyancy-driven natural circulation. This means that no pumps are needed to circulate water through the reactor. Water is heated as it passes over the core, and as it heats up, the water rises through the central riser within the interior of the vessel.

The NIST-2 facility provides nuclear qualified systems data to validate NuScale's cutting-edge thermal hydraulic safety analysis computer codes as needed for U.S. Nuclear Regulatory Commission design certification, including flow stability, long-term cooling tests, and loss of coolant accident events known as "LOCA" events.

We do not test with nuclear fuel as the power source at the NIST-2 facility, as the prototype there includes an electrically-heated core to bring the system up to operating temperature and pressure. Stability testing ensures that throughout the expected operating conditions, natural circulation flow is stable throughout the expected operating conditions for a NuScale Power Module. However, NuScale has conducted Fuels Thermal Hydraulic and Mechanical testing at Framatome's Richland Test Facility (RTF) in Richland, Washington and these tests were audited by the U.S. Nuclear Regulatory Commission (NRC).

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Question: *Are there reports available?*

Response: NuScale has a range of technical publications available and you can find them on our website at https://www.nuscalepower.com/technology/technical-publications. Additional publications are forthcoming. You may also be interested our 2013 publication titled *Overview of NuScale Testing Programs.*

Question: [Regarding nuclear fuel testing] *If not, why not, and when do you expect to make such a test?*

Response: NuScale has conducted Fuels Thermal Hydraulic and Mechanical testing at Framatome's Richland Test Facility (RTF) in Richland, Washington and these tests were audited by the U.S. Nuclear Regulatory Commission (NRC).

NuScale's fuel assembly design is based on Framatome's long-proven U.S. 17x17 pressurized water reactor (PWR) technology used in the existing nuclear fleet. However, NuScale's reactor core is approximately 6ft tall—about half the height—of existing fuel assemblies. Framatome and NuScale have worked on the manufacturing of fuel assemblies for the NuScale Power Module which are based on conventional ceramic uranium dioxide (UO_2) fuel. UO_2 fuel has a long history of testing and use in the nuclear industry.

Question: *The uniqueness of the NuScale SMR concept rests squarely on the unique fuel and cooling that make it inherently safe, to shut down independently of outside power. It is the first reactor of this type to go into construction. Why should anybody invest in a power system whose fundamental basis has never seen a test of all its parts?*

Response: Let me first address the concepts of uniqueness with regard to NuScale's SMR technology and the fuel that will be used.

The fuel that the NuScale Power Module™ will use is not unique to NuScale and is a well-established and tested fuel with a long history of use in the nuclear industry. Framatome and NuScale worked on the manufacturing of fuel assemblies for the NuScale Power Module which are based on conventional ceramic uranium dioxide (UO2) fuel. UO_2 fuel has a long history of testing and use.

As discussed in the previous section, NuScale's fuel assembly design is also based on Framatome's long-proven U.S. 17x17 pressurized water reactor (PWR) technology used in the existing nuclear fleet. However, NuScale's reactor core is approximately 6ft tall—about half the height—of existing fuel assemblies.

Next, with regard to the uniqueness of NuScale's SMR design, the concept of smaller reactors is not new and there have been many hundreds of smaller power reactors[1] built for naval use (up to 190 MW thermal). However, NuScale has improved with many design innovations and has also conducted rigorous research that demonstrates the unique resilience of the NuScale

[1] The International Atomic Energy Agency (IAEA) defines 'small' as under 300 MWe, and up to about 700 MWe as 'medium' – including many operational units from the 20th century.

power plant. For example, our Triple Crown For Nuclear Plant Safety™ is a first for commercial nuclear power—the NuScale Power Module can safely shut down and self-cool, indefinitely, with no need for operator or computer action, AC or DC power, or additional water to ensure that the shutdown and self-cooling process occurs.

The NuScale power plant also offers mission critical facilities a level of certainty for achieving the "Five 9s" (99.999 percent) for highly reliable power. A 720 MWe (gross) NuScale 12-module power plant can assure 120 MWe net power to a dedicated microgrid at 99.95% reliability over the 60-year lifetime of the plant, while 60 MWe (gross) of power can be provided at a remarkable 99.98% reliability. The unique resilience features of the NuScale power plant include:

Black-Start and Island Mode: Following a loss of offsite power event, a single NuScale Power Module™ (NPM) can be Black-Started from cold conditions and continue to power the entire plant without the plant being connected to the grid. This is referred to as operating in Island Mode.

First Responder Power: If a loss of transmission system grid occurs, the NuScale plant employs variable (0% to 100%) steam bypass so that all 12 modules can remain at power operating in Island Mode and be available to provide electricity to the grid as soon as the grid is restored.

Resilience to Natural Events: In the NuScale plant, the modules and fuel pool are located below grade in a Seismic Category 1 Building that is capable of withstanding a Fukushima type seismic event and can withstand hurricanes, tornados, and floods.

Resilience to EMP/GMD Events: The NuScale plant has numerous geomagnetic disturbance (GMD) and electromagnetic pulse (EMP) resilience features, including plant safety equipment that is electrically isolated from the main plant distribution system, a reactor vessel shielded by a stainless steel containment vessel, a GMD/EMP hardened concrete reactor building with steel liner and reinforced steel rebar, and widespread use of optical fiber links that are not susceptible to GMD/EMP.

Resilience to Aircraft Impact: The NuScale power plant reactor building is able to withstand aircraft impact as specified by the U.S. Nuclear Regulatory Commission (NRC) aircraft impact rule.

Cybersecurity: Module and plant protection systems are non-microprocessor based using field programmable gate arrays that do not use software and are therefore not vulnerable to internet cyber-attacks.

These resilience features are bolstered by NuScale's Triple Crown for Nuclear Safety™, which means that even upon loss of grid power, no operator or computer actions, AC or DC power, or additional water is needed to keep the reactors safe—a first for commercial nuclear power that provides an unlimited coping period. Our plant design incorporates several simple, redundant, and independent safety features offering unparalleled system resilience, which we continue to improve upon. To learn more about the level of resilience that the NuScale plant offers, visit our Built for Resilience webpage at https://www.nuscalepower.com/Benefits/Built-for-Resilience.

Finally, I would like to more specifically address the question *Why should anybody invest in a power system whose fundamental basis has never seen a test of all its parts?* as well as the statement *Nothing has been tested and it's all on paper*.

NuScale's Strong Track Record of Testing, Innovation, and Technology Validation

Over the past 50 years, pressurized water-cooled reactors have benefited from billions of dollars of research and development and millions of hours of operating experience. NuScale's new modular light water reactor is premised on the well-established nuclear technology principles and associated research and development (R&D), which provides a strong foundation for the cutting-edge technology validation and testing of the NuScale Power Module™ we demonstrate at state-of-the-art facilities worldwide (and continue to do so), including:

- NuScale Integral System Test (NIST-2) facility located at Oregon State University in Corvallis, Oregon
- Fuels Thermal Hydraulic and Mechanical testing at Framatome's Richland Test Facility (RTF) in Richland, Washington
- Critical Heat Flux testing at Stern Laboratories in Hamilton, Ontario Canada
- Critical Heat Flux testing at Framatome's KATHY loop in Karlstein, Germany
- Control Rod Assembly (CRA) drop / shaft alignment testing at Framatome's GmbH Technology Center in Erlangen, Germany
- Steam Generator Thermal Hydraulic Performance testing at SIET SpA in Piacenza, Italy
- Steam Generator Flow Induced Vibration (FIV) testing at SIET SpA in Piacenza, Italy
- Steam Generator Inlet Flow Restrictor testing at Alden Laboratory, Holden, MA, USA
- Emergency Core Cooling System (ECCS) Valve Proof of Concept, Demonstration and Proof Tests, Target Rock, NY, USA

Information obtained from these tests is used to validate our thermal-hydraulic and design computer models for predicting the thermal efficiency, performance, and safety of NuScale's small modular reactor technology. Data from these tests also is used to validate our reactor design and to gain manufacturing, assembly, and material handling insights.

Since 2012 NuScale has also engaged in more than 20 research projects at a geographically diverse number of universities, including two international universities and continues to engage in new opportunities. The growing relationship between NuScale and the academic community is a natural partnership spurred by a mutual spirit of imagination, creativity and innovation. In addition to our strong collaboration with universities, NuScale has engaged in research collaborations with 17 different companies and 8 national laboratories. NuScale is proud to collaborate with worldwide state-of-the-art testing facilities to complement and inform the safety-related work it conducts at NIST-2 in Oregon.

Beyond the NIST-2 facility in Oregon, NuScale built two other facilities that serve as research and learning tools and help communicate to diverse audiences the unique features and functionality of NuScale's SMR technology. Most importantly, these facilities reinforce NuScale's testing-related work to provide the safest and most resilient small modular reactor nuclear power plant that the world has ever seen. We describe these facilities in the sections that follow.

The NuScale Power Plant Control Room Simulator

In 2012, NuScale also commissioned the world's first small modular reactor power plant control room simulator, which is located at NuScale's Corvallis, Oregon office.

The simulator consists of 12 reactor control terminals and work stations for the operating crew. The purpose of the simulator facility is to demonstrate NuScale's concept of operation and plant technology to the U.S. Nuclear Regulatory Commission (NRC) and other stakeholders. The simulator has been used in the design certification process, for analysis of the Human-System Interface design, controls system strategy and to develop operating procedures.

Before, simulators were *built after* the power plant was built to train and license operators. NuScale is using the simulator to investigate how the human-system interface will function and is also using it to demonstrate to the NRC that its staffing plan is acceptable for the operation of the power plant. This facility demonstrates that up to 12 NuScale small modular reactors and their associated support systems can be safely operated from one control room by licensed operators.

Operating 12 units from a single location is also an industry first. The attributes of the NuScale design – the passive nature of the safety systems, the fact it doesn't need safety-related AC or DC power or operator action for design basis events – means that it is much safer and simpler to operate than today's conventional reactors.

The simulator was constructed to model the all-digital NuScale power plant control room. Software models provide high fidelity, full-scope, real-time simulation of each of the 12 reactor cores, the thermal hydraulics associated with each of the 12 units, and the power plant's electrical system. It provides the indications, alarms, controls, procedures, and automations to safely and reliably control a NuScale plant during a variety of normal and off-normal events.

NuScale Upper Module Mockup

In May of 2015, NuScale publicly announced completion of a full-scale mockup of the upper one third of the NuScale Power Module. Referred to as the "Upper Module Mockup", the facility affords NuScale visitors from around the world a hands-on opportunity to explore and learn about our groundbreaking small modular reactor technology from the inside out.

The Upper Module Mockup includes accurately sized and located components of the NuScale Power Module, providing NuScale engineers with important insights into the inspection and maintenance activities that are essential to plant operation.

It consists of the top assembly of the NuScale Power Module from the upper module access platform down to the elevation of the reactor vessel head—which is considered as the upper one third of the module. The access platform is where a NuScale power plant worker can disconnect piping (points to piping systems and disconnect flanges/show in video) and cables (which aren't mocked up).

Major components that comprise the Upper Module Mockup that the visitor and engineers can see and learn about include:

- The upper portion of the containment vessel
- Reactor vessel head
- The main steam piping (points/show in video) is the primary method for removing heat from the core of the reactor

- Other major piping for feed water and chemical volume & control system or CVCS
- Control rod drive mechanisms, and
- Major valves such as isolation valves and emergency core cooling system or “ECCS” valves.

The Upper Module Mockup is a full size and dimensionally accurate steel model of the upper portion of the module that is used for spatial orientation and human factors analysis in connection with access and maintenance considerations. The facility also provides NuScale engineers the ability to plan for worker safety and compliance with Occupational Safety and Health Administration requirements. It also supports radiation protection planning—ALARA, which stands for “as low as reasonably achievable”—to minimize exposure time for refueling and maintenance workers as well as maintenance planning, inspection planning, and fabrication planning. It is a learning tool to help communicate the scale and layout of the NuScale Power Module™ to diverse audiences including the design team, customers, regulators, the media, and the general public.

Question/Statement: *The 20% gain in capacity is a direct result of the fuel being enriched*.

Response: Regarding NuScale’s 2018 announcement about the ability to generate 20% more power than originally planned from our SMR technology, the NuScale Power Module™:

NuScale conducted state-of-the-art prototypical testing and computer modeling of the fuel for and helical steam generators of the NuScale Power Module which demonstrated that the 160 MWt module can produce 200 MWt—a 20% increase in generating capacity that still fully satisfies design and regulatory requirements. NuScale has completed more than $70 million dollars in hardware tests, including this comprehensive testing of the fuel and helical coil steam generators, which has provided data used to validate and refine the predictive ability of our advanced thermal hydraulic safety analysis computer codes.

This 20% increase in power is actually quite common in the nuclear industry, as nearly all U.S. nuclear plants have undergone uprate processes. According to the U.S. Nuclear Regulatory Commission (NRC), “utilities have used power uprates since the 1970s as a way to generate more electricity from their nuclear plants. As of April 2018, the NRC has approved 164 uprates, resulting in a gain of approximately 23,769 MWt (megawatts thermal) or 7,923 MWe (megawatts electric).” You can view the list of these uprates on the NRC website. The NRC states that collectively, these uprates have added generating capacity equivalent to about eight new reactors.

NuScale’s 20% gross output increase means significant savings and increased competition with other electricity generation sources, with the same unparalleled safety and zero impact in the U.S. NRC design certification review process.

With the 20% increase in NuScale SMR power output, the enrichment level of the fuel will remain below the 5% limit and the average burnup will remain about the same. Fuel “burnup” describes how much uranium has been utilized in a reactor and is represented in gigawatt-days per metric ton of uranium (GWd/MTU). The longer the fuel spends in the reactor, the higher the burnup. The enrichment level of fuel is the weight percent of U235, which is different than burnup, and is limited by regulation to less than 5% for commercial nuclear power plants. Even with the increased power output to 683 MWe net (720 MWe gross), the number of fuel assemblies remains unchanged at 37.

Question: *What is the status of the fabrication plant?*

Response: The NuScale Power Module (NPM) design is manufacturer-agnostic because NuScale controls the design and, as a result, can utilize any qualified pressure vessel manufacturer to “build to print” the module. During NuScale supply chain development activities, NuScale engaged with approximately 40 qualified and experienced pressure vessel fabricators worldwide and at that time determined that NuScale will utilize existing factories to fabricate the NPM in lieu of building its own factory. The major module subcomponents will be manufactured at multiple manufacturer locations and shipped to a single location for assembly prior to installing into the facility. NuScale is currently contracted with both BWX Technologies and Doosan Heavy Industries and Construction to assist NuScale with its final design for manufacturing. NuScale maintains communications with several other vessel manufacturers for the potential to add future capacity as needed.

If you have any further questions, please do not hesitate to contact me at 541-360-0569 or mmiller@nuscalepower.com.

Sincerely,

Mike Miller Digitally signed by Mike Miller
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Mike Miller
CFPP Project Manager

