RAIO-0119-64307

January 29, 2019

Docket: PROJ0769

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 9390 (eRAI No. 9390) on the NuScale Topical Report, "Loss-of-Coolant Accident Evaluation Model," TR-0516-49422, Revision 0

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 9390 (eRAI No. 9390)," dated June 15, 2018
2. NuScale Topical Report, "Loss-of-Coolant Accident Evaluation Model," TR-0516-49422, Revision 0, dated December 2016

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) response to the referenced NRC Request for Additional Information (RAI).

The Enclosures to this letter contain NuScale's response to the following RAI Question from NRC eRAI No. 9390:

- 15.06.05-18

RAI Question 15.06.05-18 includes four parts, (a), (b), (c), and (d). The enclosure to this letter provides NuScale's response to parts (a), (b), and (c). The NuScale response to part (d) will be provided along with RAI Question 15.06.05-19 by February 08, 2019.

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 9390 (eRAI No. 9390). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 3) supports this request. Enclosure 2 is the nonproprietary version of the NuScale response.

This letter and the enclosed responses make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Paul Infanger at 541-452-7351 or at pinfanger@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

Distribution: Gregory Cranston, NRC, OWFN-8H12
Samuel Lee, NRC, OWFN-8H12
Rani Franovich, NRC, OWFN-8H12

Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9390, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9390, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0119-64308

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Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9390, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9390, nonproprietary

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 9390
Date of RAI Issue: 06/15/2018

NRC Question No.: 15.06.05-18

Title 10, Part 52, of the Code of Federal Regulations (10 CFR Part 52), "Licenses, Certifications, and Approvals for Nuclear Power Plants," Section 52.47, "Contents of Applications; Technical Information" (10 CFR 52.47), specifies that an application for certification of a nuclear power reactor design that uses simplified, inherent, passive, or other innovative means to accomplish its safety functions must meet the requirements of 10 CFR 50.43(e) (52 Part 52.47(c)(2)). 10 CFR 50.43(e) requires, in part, assessment of the analytical tools used for safety analyses over a sufficient range of normal operating conditions, transient conditions, and specified accident sequences. Regulatory Guide (RG) 1.203 describes a process that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in developing and assessing evaluation models that may be used to analyze transient and accident behavior that is within the design basis of a nuclear power plant. As stated in RG 1.203, an evaluation model (EM) is the calculational framework for evaluating the behavior of the reactor system during a postulated transient or design-basis accident. As such, the EM may include one or more computer programs, special models, and all other information needed to apply the calculational framework to a specific event, as illustrated by the following examples:

1. Procedures for treating the input and output information (particularly the code input arising from the plant geometry and the assumed plant state at transient initiation)

2. Specification of those portions of the analysis not included in the computer programs for which alternative approaches are used

3. All other information needed to specify the calculational procedure

The entirety of an EM ultimately determines whether the results are in compliance with applicable regulations. Therefore, the development, assessment, and review processes must consider the entire EM.

a. The NIST-1 facility was sized based on scaling the natural circulation phase at {{ }}2(a),(c), which the staff audited in support of the loss of coolant accident [LOCA] Topical Report [TR]). As the reactor will be in steady state for natural circulation, the two dominant phenomena, buoyancy and friction should match. {{ }}2(a),(c) steady state operation, as these two forces will be balanced as was shown in Section 4.4.1 {{ }}2(a),(c). Please explain this discrepancy.

b. Regarding depressurization equations for the system {{ }}2(a),(c), the staff is concerned that {{ }}2(a),(c) may not be properly preserved. Therefore, the current approach could average the effect of heat addition over the whole primary system. As a result, the depressurization rate could be distorted as the impact of heat addition might be diluted in the reactor pressure vessel (RPV) and similarly the pressurization rate in the containment could be also be altered. Please provide justifications to show this {{ }}2(a),(c) and approach does not adversely impact the blow-down phenomenon simulation in NIST.

c. The scaling report {{ }}2(a),(c) showed that there is distortion in {{ }}2(a),(c). At peak CNV pressure {{ }}2(a),(c). Also, at the peak pressure, all terms in the energy equation should be balanced, i.e, the energy input from the RPV and the energy lost to the containment wall surface should be equal. This is not evident from Table 6-20. Please explain. {{ }}2(a),(c) for CNV pressure indicates {{ }}2(a),(c). What are additional distortions that compensate for it?

d. Because the Section 8.3.2 only has a brief summary of the scaling analysis and distortion evaluation based on the actual scaling report and distortion analysis for NIST, however these evaluations form a large portion of the justification for the model, provide important findings and conclusions from the scaling analysis report and the distortion evaluation report with specific references (e.g. section/page/figure number) that support the conclusions in Section 8.3.2." These findings should also include distortions in power distribution, initial fluid and heat structure stored energy in the vessel, NIST CNV initial conditions; such as pressure, CNV wall temperature, HTP temperature, condensate liquid level, building pool temperature, and NIST initial vessel pressure, and the impact of these distortions on the test data for figures of merit. The accurate documentation of initial and boundary conditions are essential for NRELAP5 code validation.

NuScale Response:

eRAI 9390, Question 15.06.05-18 includes four parts, (a), (b), (c), and (d). This letter provides NuScale's response to parts (a), (b), and (c).

1. Introduction:

The scaling methodology developed for the design and construction of NuScale Integral System Test (NIST-1) facility to simulate NuScale Power Module (NPM) Loss of Coolant Accident (LOCA) is presented in Section 8.3.2 of Reference [1]. The top-down portion of the scaling analysis is revised using the final NPM design and as-built NIST-1 facility dimension to include

- Updated steady state natural circulation analysis
- Reactor Circulation System (RCS) and Containment Pressure Vessel (CNV) mass/energy balance over the unique phases of NPM LOCA

The purpose of the revised analysis is to re-define the mass/energy balance equations to include additional terms to better quantify the distortion in various phenomena in both RCS and CNV during a typical NPM LOCA scenario. The control volume balance equations derived as consistent with the discussion given in Reference [2] for both RCS and CNV are

- Total mass balance,
- Liquid (inventory) balance with wall and bulk phase change rates, and
- Energy balance written in the form of pressure-rate equation.

For quantifying the distortion, the following additional terms in the energy balance equations are explicitly accounted for:

- {{

}}2(a),(c)

By identifying the characteristic scales appearing in the balance equations, the dimensionless form of the mass/energy balance equations and the definitions of the Π groups characterizing the ratio of the characteristic times for each process are determined.

By using NRELAP5 for both NPM and as-built NIST-1 facility, the top-down portion of the scaling analysis is performed to quantify the distortions by considering

- Steady state natural circulation for both NPM and NIST-1 and the key dimensionless numbers previously determined
- Typical liquid-space and steam-space LOCA scenarios as well as inadvertent opening of a single Reactor Vent Valve (RVV)

The NIST-1 facility RCS {{

}}2(a),(c)

In Section 2, the capability of the NIST-1 facility in simulating the steady-state natural circulation flow is discussed by examining different NPM and NIST-1 operating conditions as response to eRAI-9390 part (a). The calculation of thermodynamic property derivatives appearing in the pressure-rate equations for both RCS and CNV through the caloric equation of state for the two-phase mixture in equilibrium are discussed in Section 3 as a response to eRAI-9390 part (b). The response to the part (c) of eRAI-9390 is presented in Section 4 by considering the Chemical Volume and Control System (CVCS) discharge line break scenario and summarizing the Π groups governing the CNV energy balance near the peak CNV pressure.

2. Steady State Natural Circulation at NPM and NIST-1:

Response to eRAI 9390 Q 15.06.05-18 (a):

Dimensional analysis of the single-phase natural circulation in NPM and NIST-1 facility is performed based on control volume energy balance and loop momentum integral equations considering {{

}}2(a),(c)

Table 1 summarizes the key results along with the operating conditions of the NPM and NIST-1 steady-state simulations with NRELAP5. {{

}}2(a),(c)

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}}2(a),(c) Based on the value of the dimensionless parameters listed in Table 1, it is concluded that the steady-state natural circulation flow can be well simulated in NIST-1 facility considering the NPM at {{ }}2(a),(c) and full RCS pressure.

3. Thermodynamic Property Derivatives:

Response to eRAI 9390 Q 15.06.05-18 (b):

As part of the top-down portion of the scaling methodology adopted for the design and construction of the NIST-1 facility, the thermal energy balance in both RCS and CNV is considered with multiple heat transfer and mass flow rate paths. The caloric equation of state for the specific internal energy of the form $u=u(\rho,p)$ with ρ as the mixture density and p as the volume-average pressure is used to transform the thermal energy balance into pressure-rate equation for both RCS and CNV.

{{

}}2(a),(c)

where p is the volume-average pressure, M is the total mass within the volume, $\rho=\frac{M}{V}$ is the mixture density with V as the total volume. In Equation (1), the first term on the right-hand-side denotes the heat transfer in and out of the control volume through the heat structures including any volumetric heat source/sink, the second term is the enthalpy-energy flow based on the difference between the enthalpy at flow junction and the volume-average mixture enthalpy, and the last term represents the mechanical response which is the change in system pressure due to the net mixture flow in or out of the control volume as discussed in Reference [2]. The thermodynamic property derivatives, F and f, in Equation (1) is defined as

{{

}}2(a),(c)

where i is the mixture specific enthalpy and u is mixture specific internal energy. In deriving the dimensionless balance equations and the governing Π groups, {{

}}2(a),(c)

where u_k is the specific internal energy and v_k is the specific volume of the phase, k ($k=f$ for liquid , $k=g$ for vapor/gas); {{

}}2(a),(c)

{{

}}2(a),(c)

The thermodynamic derivatives given in Equations (2) and (3) are determined from the equation of state given in Equation (6). While the second thermodynamic derivative can be determined from the saturation line

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}}2(a),(c)

the first thermodynamic property, F can be evaluated numerically as a function of pressure and mixture density (or mass for a fixed volume). Figure 1 illustrates the variation of these thermodynamic property derivatives in Equation (1) as a function of both pressure and mixture density. It is important to note that the mass fraction of the gas phase is related to the volume fraction of the same phase from

$$x = \frac{\alpha \rho_g}{\rho} \tag{8}$$

where α is the volume-average volume fraction of the gas phase or simply the void fraction.

4. CNV Energy Balance near Peak Pressure

Response to eRAI 9390 Q 15.06.05-18 (c):

As discussed previously, the control volume mass/energy balance equations are used to characterize the processes occurring in both RCS and CNV considering multiple heat and mass flow paths. Based on the detailed derivations and the definitions of the Π groups in the dimensionless mass/energy balance in the revised top-down scaling analysis. Table 2, 3, and 4 summarize the mass flow paths, heat flow paths for the RCS, and CNV, respectively. The heat and mass flows into the control volume have positive sign; whereas the negative sign represents heat and mass flow out of the control volume. Three mass flow rates are identified for both NPM and NIST-1 and they are symmetric between RCS and CNV. The same number of heat flow paths are identified for the RCS in NPM and NIST-1. {{

}}2(a),(c)

{{

}}2(a),(c)

By choosing the reference values for each variable appearing in the mass/energy balance equations, the dimensional analysis is performed to derive the Π groups representing the characteristic time ratios of various processes in both RCS and CNV. The summary of the Π groups in the dimensionless mass/energy balance equations is given in Tables 5 and 6. As depicted in Tables 5 and 6, the heat transfer through the HTP as well as CNV shell in the NIST-1facility are described through their own Π groups. The contribution to the inventory balance through these heat transfer paths are also explicitly accounted for the NIST-1 facility to identify the distortion introduced via the CNV shell.

Through NRELAP5 simulations, three scenarios are considered in the distortion analysis:

- 100 percent discharge line break on the CVCS line (HP06)
- 100 percent high point vent line break (equivalent to pressurizer spray line break) (HP07)
- Inadvertent opening of a single RVV (HP09)

In order to respond to the eRAI-9390 part c, {{

}}2(a),(c) The comparison of the pressure transient in both RCS and CNV is illustrated in Figure 2. The liquid inventory variations in both RCS and CNV are depicted in Figure 3. The timing of key events in the simulations for both NPM and NIST-1 is given in Table 7. {{

}}2(a),(c)

Two approaches are utilized in quantifying the distortions in NIST-1 by using the NRELAP5 simulations:

- Snapshot approach where the snapshots at selected instants with reference values corresponding to the particular instant during the unique phases of LOCA as described in Reference [1]
- Π groups calculated as a function of time during the phases 1a, 1b, and 2 of the LOCA where the reference quantities are selected at each time step

The reference flow rate {{

}}2(a),(c) The sum of the Π groups on the CNV energy balance is also plotted during this phase as illustrated in Figure 5. The sum of these Π groups crosses the zero line when it coincides with the occurrence of the peak CNV pressure.

References:

[1] TR-0516-49422, “Loss of Coolant Accident Evaluation Model”, Revision 0, December 2016.

[2] Wulf, W. 1996, “Scaling of thermohydraulic systems”, Nucl. Eng. Desg. Vol. 163, pp:359-395.

Table 1. Steady-state Single-phase Natural Circulation in NPM and NIST-1

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}}2(a),(c)

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{{

}}2(a),(c)

Figure 1. Thermodynamic Property Derivatives from Caloric Equation of State for the Two-phase Mixture in Equilibrium

Table 2. Mass Flow Paths for NPM and NIST-1 (RCS and CNV)

Flow Path No	Description
$j = 1$	Break flow (discharge or high point vent line)
$j = 2$	Total Reactor Recirculation Valve (RRV) flow (2 RRVs)
$j = 3$	Total Reactor Vent Valve (RVV) flow (3 RVVs)

Table 3. Heat Flow Paths for RCS in NPM and NIST-1

Heat Flow Path No	Description
$m = 1$	Core heat transfer
$m = 2$	Steam Generator heat transfer
$m = 3$	Reactor Pressure Vessel inner wall heat transfer
$m = 4$	Reactor Pressure Vessel internal stored energy release

Table 4. Heat Flow Paths for Containment in NPM and NIST-1

Heat Flow Path No	Description
$m = 1$	Reactor Pressure Vessel outer wall heat transfer (NPM only)
$m = 2$	Containment inner wall heat transfer
	Heat transfer on the heat transfer plate (HTP) inner surface (NIST-1)
	Heat transfer on the Containment shell inner surface (NIST-1)

Table 5. Description of the Π Groups for the RCS Mass/Energy Balance

Π Group	Description
Total Mass Balance:	
Π_1	Total mass flow rate (choked/un-choked) through the break
Π_2	Total mass flow rate (choked/un-choked) through the RRVs
Π_3	Total mass flow rate (choked/un-choked) through the RVVs
Liquid (Inventory) Balance:	
$\Pi_{f,1}$	Liquid mass flow rate through the break
$\Pi_{f,2}$	Liquid mass flow rate through the RRVs
$\Pi_{f,3}$	Liquid mass flow rate through the RVVs
Π_w	Vapor generation rate due to the wall heat transfer
Π_b	Vapor generation rate due to flashing (bulk phase change)
Energy Balance (Pressure Equation):	
Π_{m1}	Core heat transfer
Π_{m2}	Steam generator heat transfer
Π_{m3}	Reactor Pressure Vessel inner wall heat transfer
Π_{m4}	Stored energy release inside RCS
Π_1'	Enthalpy-difference flow through the break
Π_1''	Mechanical response due to the total break flow
Π_2'	Enthalpy-difference flow through the RRVs
Π_2''	Mechanical response due to the total RRV flow
Π_3'	Enthalpy-difference flow through the RVVs
Π_3''	Mechanical response due to the total RVV flow

Table 6. Description of the Π Groups for the Containment Mass/Energy Balance

Π Group	Description
Total Mass Balance:	
Π_1	Total mass flow rate (choked/un-choked) through the break
Π_2	Total mass flow rate (choked/un-choked) through the RRVs
Π_3	Total mass flow rate (choked/un-choked) through the RVVs
Liquid (Inventory) Balance:	
$\Pi_{f,1}$	Liquid mass flow rate through the break
$\Pi_{f,2}$	Liquid mass flow rate through the RRVs
$\Pi_{f,3}$	Liquid mass flow rate through the RVVs
Π_w	Vapor generation rate due to the wall heat transfer
	Vapor generation rate due to the wall heat transfer on the HTP (NIST-1)
	Vapor generation rate due to the wall heat transfer on the Shell (NIST-1)
Π_b	Vapor generation rate due to flashing (bulk phase change)
Energy Balance (Pressure Equation):	
Π_{m1}	Reactor Pressure Vessel outer wall heat transfer (not exist for NIST-1)
Π_{m2}	Containment inner wall heat transfer
	Heat transfer on the HTP (NIST-1)
	Heat transfer on the Containment Shell (NIST-1)
Π_{pool}	Heat transfer to the Reactor Cooling Pool (not part of the CNV energy balance)
$\Pi_1^{'}$	Enthalpy-difference flow through the break
$\Pi_1^{''}$	Mechanical response due to the total break flow
$\Pi_2^{'}$	Enthalpy-difference flow through the RRVs
$\Pi_2^{''}$	Mechanical response due to the total RRV flow
$\Pi_3^{'}$	Enthalpy-difference flow through the RVVs
$\Pi_3^{''}$	Mechanical response due to the total RVV flow

{{

}}[2(a),(c)]

Figure 2. RCS/CNV Pressure Transient for the 100 percent Discharge Line Break (HP06)

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}}[2(a),(c)]

Figure 3. RCS/CNV Inventory Balance for the 100 percent Discharge Line Break (HP06)

Table 7. Comparison of Timing of Key Events for 100 percent Discharge Line Break (HP06)

Event	NPM	NIST-1
{{		
		}}2(a),(c)

Table 8. Summary of Key Quantities at the Snapshot near Peak CNV Pressure for HP06

Quantity	NPM	NIST-1	Ratio
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			}}2(a),(c)

Table 9. Π Group Summary for CNV Balance near Peak CNV Pressure (HP06)

Total Mass Balance:	NPM	NIST-1	DF%
{{			
			}}2(a),(c)

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}}2(a),(c)

Figure 4. Variation of Π Groups in RCS and CNV Balance around ECCS Actuation (HP06)

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}}2(a),(c)

Figure 5. Variation of the Sum of Π Groups in CNV Energy Balance around ECCS Actuation (HP06)

Impact on Topical Report:

There are no impacts to the Topical Report TR-0516-49422, Loss-of-Coolant Accident Evaluation Model, as a result of this response.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0119-64308

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

1. I am the Director, Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale.
2. I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:
    a. The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.
    b. The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.
    c. Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.
    d. The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.
    e. The information requested to be withheld consists of patentable ideas.
3. Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying Request for Additional Information response reveals distinguishing aspects about the method by which NuScale develops its loss of coolant accident analysis.

    NuScale has performed significant research and evaluation to develop a basis for this method and has invested significant resources, including the expenditure of a considerable sum of money.

    The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

    If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

4. The information sought to be withheld is in the enclosed response to NRC Request for Additional Information No. 9390, eRAI No. 9390. The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.
5. The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).
6. Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:
    a. The information sought to be withheld is owned and has been held in confidence by NuScale.
    b. The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.
    c. The information is being transmitted to and received by the NRC in confidence.
    d. No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.
    e. Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on January 29, 2019.

Zackary W. Rad