Responses to Submitter's Comments in February 14, 2022, Letter to the Executive Director for Operations (EDO)[1]

In the table below, the Office of Nuclear Reactor Regulation (NRR) staff provides its responses to comments in the submitter's letter to the EDO in response to the EDO's decision on Differing Professional Opinion (DPO) case number DPO-2020-004.[2]

Comment # [Staff Assigned]	Reference to Submitter's Letter	Submitter's Comment	NRR Staff's Response
Comments Regarding DPO Appeal Issue 1 DPO Appeal Issue 1, as stated in the EDO decision**:** *The NuScale reactor building design is incomplete, inadequate, and unsafe for the design basis earthquake [DBE] (safe shutdown earthquake [SSE] / Certified Seismic Design Response Spectra [CSDRS]). This is primarily because no design modifications were made when demand forces exceeded capacity.*			
1A	February 14 Letter at 2 available at DPO-2020-004 Case File at 105	… The more ductile of a structural element, the more stress excessive over the (elastic) capacity can be redistributed to its neighboring structural elements. A structural analysis is required under such a condition and the analysis result will show whether the structural element can redistribute the excessive stress over its (elastic) capacity to its neighboring structural elements or not without failure. No one should use his/her judgement to determine whether the stress redistribution is possible or not and how much and to how many structural elements because that subjective approach has no basis just like the "stress averaging" issue in issue #1. This is a structural analysis issue not a judgment issue.	The NRR staff disagrees with the comment. Resolution of localized demand-to-capacity exceedances from linear elastic analysis is not generally a safety-significant structural analysis issue. Resolving these exceedances by averaging with adjacent elements after assessing the specific area or element(s) with exceedance is a normal, accepted approximation in professional engineering practice and applicable to the NuScale design. This approach has satisfactorily achieved results consistent with the expected performance goal (limit state) of essentially elastic structural behavior (i.e., allowing for only limited localized damage and/or inelastic behavior). For the NuScale design, the overwhelming majority of elements meet code acceptance criteria

[1] Letter dated February 14, 2022, from John Ma to EDO titled "Respond and Request to EDO" (February 14 Letter), at pp. 104 – 111 of the DPO-2020-004 Case File, redacted, public version, Agencywide Documents Access and Management System (ADAMS) Accession No. ML22056A017.
[2] Memorandum from D. Dorman to J. Ma, "Differing Professional Opinion Appeal Concerning DPO-2020-004," dated February 8, 2022, ADAMS Accession No. ML22021B617.

Enclosure 2

			on an element-basis (without further evaluation or averaging) based on demands from linear elastic analyses. This fact provides sufficient assurance of the general essentially elastic behavior of the relevant NuScale structures. Since the structural analysis and design process involves making appropriate modeling idealizations, assumptions, and approximations, the structural analyst and engineer(s) of record are expected to interpret analysis results and exercise professional engineering judgements, consistent with expected structural behavior and analysis objectives.
1B	February 14 Letter at 2 available at DPO-2020-004 Case File at 105	I want to point out that (1) the AISC [N690-18] standard is only applicable to steel structures and steel material is inherently ductile, and does not apply to concrete structures, such as the NuScale reactor building, because concrete material is brittle, and (2) if the "stress averaging" is limited to no larger than twice the section thickness for ductile steel material, how could anyone justify the use of "stress averaging" with four times the section thickness for brittle concrete material for the NuScale reactor building as stated in the NuScale DC [design certification] application?	The NRR staff disagrees with the comment in part. The NRR staff agrees that concrete material is inherently brittle under certain load conditions. Physical characteristic can be improved through well-designed structures using steel reinforcement or steel composite (SC) construction. The stress averaging provision mentioned in the comment is only applicable to SC construction addressed by the new Appendix N9, "Steel-plate Composite (SC) Walls" of ANSI/AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities."[3] It is not applicable to steel or reinforced concrete structures. The ANSI/AISC N690-18 specification has no stress averaging requirements for steel structures, its primary scope, and the ACI 349-06[4] code has no stress averaging requirements for reinforced concrete structures.

[3] American Institute of Steel Construction Standard ANSI/AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities," Appendix N9, "Steel-plate Composite (SC) Walls," June 28, 2018.
[4] American Concrete Institute Code, ACI 349-06, "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary." ACI 349-06 is the code of record for the NuScale reinforced concrete design.

			SC construction is a relatively new composite concept consisting of plain concrete sandwiched between two steel faceplates. Since reinforced concrete has superior ductility characteristics compared to SC construction, and better ability to redistribute forces and moments through cracking, even prior to reinforcing steel (rebar) yielding, as well as by rebar yielding, reinforced concrete structures are able to redistribute forces and moments over lengths used in the NuScale analysis as reviewed by the NRR staff.
1C	February 14 Letter at 3 available at DPO-2020-004 Case File at 106	The above excerpt from the EDO's letter does not include the example that I provided in my DPO report and in Appeal to EDO report. That example has a structural element with D/C > 3.0 [i.e., D/C = 3791/1184 = 3.2], much greater than the D/C > 0.8, and used **ten** structural elements, many more than the three elements as stated above, for "stress averaging". That example in my Appeal to EDO report is copied below: *"The in-plane shear force (the demand) acting on Element number 4942 is 3791 kips (1 kip = 1000 pounds) but the structural element only has a shear capacity (or strength) of 1184 kips. The force (the demand) acting on the element is more than three times greater than its capacity. No design modification was done, and no post-yield structural element properties were created and used to capture the condition or behavior of these overstressed structural elements when the reactor building is only subjected to the design-basis (CSDRS) earthquake. The applicant arbitrarily brought down the high shear stress by averaging the shear stress of ten structural elements (see*	The NRR staff disagrees with this comment. Although the EDO's letter did not explicitly mention element 4942, in Item 6, Enclosure 1, the NRR staff has provided a detailed assessment of in-plane shear, including exceedances for element numbers 4942, which is discussed by the DPO submitter, and 4951. These elements are reentrant corner elements at the north and south ends of the top of the short partition weir wall along reactor building (RXB) grid line 3, as shown in DCA Part 2, Tier 2, Figures 3B-10 and 3B-11. In Item 6, the NRR staff discussed how NuScale addressed in-plane shear in two ways. Briefly, NuScale addressed the issue by incorporating it in the main reinforcing steel design based on element demands and by performing an additional gross structural wall check, consistent with provisions in Section 21.7.4 and the related Section 11.10 of the ACI 349-06 code. As stated in the Item 6, the NRR staff's review concluded that the applicant addressed in-plane shear, including the example cited by the submitter, in an acceptable and appropriate manner.

		page15 in my DPO report).” (emphasis in original)	

<u>Comments Regarding DPO Appeal Issue 2</u>:
DPO Appeal Issue 2, as stated in the EDO decision: *Structural collapse due to shaking from the review level earthquake (RLE) was not evaluated for the NuScale reactor building, so there is no seismic margin incorporated into the structural design. This is, in part, because the NRC has not provided a definition or interpretation of the NRC policy in SECY-93-087 with respect to seismic margin. Using a probabilistic risk assessment (PRA) method alone for evaluation of building safety at the RLE is incorrect.*

2	February 14 Letter at 3-8 available at DPO-2020-004 Case File at 106-111	I am not disputing the adequacy of the EDO’s answer, but the above answer does not address or apply to my DPO issue. My DPO issue is not about the PRA-based seismic margin analysis for the entire **<u>plant</u>**. My DPO issue is about that the required seismic margin for the reactor **<u>building</u>** has not been designed into the building. The PRA-based seismic margin analysis for the entire **<u>plant</u>** and the required seismic margin for the single reactor **<u>building</u>** are two different subjects that require two different approaches. The former belongs to the discipline (or field) of probability while the latter belongs to the discipline of structural engineering. The reason that no seismic margin had been designed into the reactor building was because the lack of recognition of this distinction between the two subjects. The lack of this distinction was caused by that the previous NRO (now NRR) management had prohibited the use of the structural engineering approach (method and process) for seismic margin design for the reactor building and replaced it by the PRA approach and moved the review responsibility from structural engineers (Structural Engineering Branch) to probabilistic risk	The NRR staff disagrees with this comment. The Executive Director for Operations (EDO) response to the Differing Professional Opinion Appeal Concerning DPO-2020-004 addressed the concern raised in the DPO submitter’s appeal. Also, the technical issues discussed in the DPO submitter’s February 14, 2022 letter are not materially different from the technical issues that the DPO submitter previously provided. As a result, the NRR staff response focuses on the DPO submitter’s concern that the seismic margin for the reactor building (RXB) could be incorrectly represented in the staff’s analysis. In response to the DPO submitter’s concerns that one could draw an incorrect conclusion from the NRR staff’s analysis about the RXB seismic robustness during a review level earthquake (RLE), the NRR staff provides additional discussion of its analysis as previously documented in the Final Safety Evaluation Report (FSER). In Section 19.1.4.8.1, “Seismic Risk Evaluation,” Chapter 19 “Probabilistic Risk Assessment and Severe Accident Evaluation,” the peak ground acceleration (pga) corresponding to the NuScale design basis safe shutdown

		analysts (PRA Branch). This management action resulted not only in no seismic margin being designed into the reactor building but also in **<u>a false claim or implication</u>** that the building possessed a seismic margin of 1.67 and would not collapse during the review level earthquake (RLE) without being noticed to causal readers. The no seismic margin analysis/design and the false claim or implication are presented and discussed below. 2.1 No seismic margin was designed into the reactor building while other important buildings have including the AP1000 shield building … 2.2 The subtly false claim or implication that the reactor building possessed a seismic margin of 1.67 and would not collapse during RLE should be corrected in the FSER for the NuScale design certification application … 2.3 The lack of distinction between the PRA-based SMA for the entire plant safety and the seismic margin for the single reactor building safety has caused the unsafe design for the reactor building … 2.4 The unsafe design of the certified reactor building and the subtle claim or implication that	earthquake (CSDRS or SSE) is 0.5g. Using the 1.67 seismic margin figure cited by the DPO submitter, the pga acceleration corresponding to that would be 0.84g. In Section 19.1.4.8.1.2, “Seismic Fragility Evaluation,” the NRC structural engineering staff reviewed the seismic fragility evaluation of structures and structural components (SSC), as documented in FSER. The staff documented that a separate fragility analysis was performed for each structure listed in DCA Part 2, Tier 2, Chapter 19, Section 19.1.5.1 “Seismic Risk Evaluation,” Table 19.1-35 “Structural Fragility Parameters and Results.” The RXB structural components evaluated included the RXB crane, RXB exterior walls, module supports, bioshield, pool walls, crane support walls, bay walls, roof, and basemat. The fragility analyses were performed using NRC-endorsed methods in DC/COL-ISG-20 (conservative deterministic failure margin method or separation of variables method). The staff also documented that it audited a summary of the fragility calculations of several PRA-critical structures, including the reactor building structures listed above, and the staff verified the assumptions, controlling failure modes, and the results of the seismic evaluation (performed by the applicant’s structural engineers) presented in DCA Part 2, Tier 2, Table 19.1-35, Table 19.1-38 “Seismic Correlation Class Information,” and Table 19.1-40 “Key Assumptions for the Seismic Margin Assessment.” The results of these structural fragility evaluations included the median seismic capacity and uncertainty parameters (randomness and modeling uncertainties). Using the fragility

		the reactor building possessed a seismic margin of 1.67 and it would not collapse are wrong and need to be corrected … 2.5 Moving the structural engineer's review responsibility to the probabilistic risk analysts is improper (this is the first time occurred in my more than 47-year service in the NRC) and that improper action resulted in unsafe design and that action should be corrected … 2.6 The two major problems for the certified reactor building and their proper Resolution The problems as stated above include (1) no seismic margin was explicitly designed into the reactor building while other important buildings have, including the AP1000 shield building, and (2) the PRA staff had concurred with the applicant's false claim or implication that the reactor building possessed a seismic margin of 1.67 and would not collapse during the RLE, which is obviously wrong…. Request #2: 2.1 The EDO needs to obtain an answer from the NRR on whether the certified reactor building will collapse during the RLE or not, and the basis for that answer, and the value	parameters, a ground motion representing high confidence (95 percent) of low probability (5 percent) of failure (HCLPF) was calculated for each SSC. The fragility parameters were then used as inputs to the PRA model for the seismic margins analysis used to determine the plant-level HCLPF. As shown in DCA Part 2, Tier 2, Tables 19.1-35 and 19.1-38, the lowest design-specific (DS) HCLPF seismic capacity values calculated for structural failure events of the RXB structural components were 0.88g for the RXB crane and 0.92g for the RXB exterior walls. Thus, these SSCs have demonstrated adequate seismic robustness when exposed to pga of 0.84g or 1.67 times the CSDRS acceleration. As documented in FSER Section 19.1.4.8.1.2, the staff verified that no SSCs with HCLPF capacities less than 0.84g, as indicated in DCA Part 2, Tier 2, Table 19.1-38, contribute to the seismic margin. In FSER Section 19.1.4.8.1.2, the staff documented its review of NuScale's assumption[5] that seismic Category I structures meet the seismic margin criteria of 1.67 times the CSDRS for site-specific seismic hazards (e.g., sliding, overturning). The staff's review concluded that it is a reasonable assumption for the purpose of the DCA. Consistent with Tier 2 COL information items, the combined license (COL) applicant will need to confirm the validity of this assumption with other Tier 2 information items as part of its COL application.

[5] NuScale DCA Part 2, Tier 2, Table 19.1-40, "Key Assumptions for the Seismic Margin Assessment," ADAMS Accession No. ML20224A508.

		(numerical number, such as 1.5 or 1.67 or any other numbers) of seismic margin that the reactor building possessed so that the public can see the adequacy of the reactor building design and its actual seismic margin value. 2.2 The EDO needs to obtain an answer from the NRR explaining its logic and reason for prohibiting the use of structural engineering approach and replacing it by the PRA approach for assessing the seismic margin and safety of the reactor building so that the public can see and judge whether such an action is proper, or it had resulted in unsafe design for the reactor building. (emphasis in original)	The EDO response acknowledges the important role that structural engineers have in the development of seismic margins analysis. Structural engineers, similar to the role of mechanical engineers in reviewing fragility analysis of mechanical and electrical equipment, review the fragility evaluation of structures and structural components including any related structural analyses. The NRC structural engineering staff actively participated and reviewed the applicant's seismic fragility evaluation of the structures and structural components (including RXB structural components) and its results (median capacity, uncertainty parameters, and HCLPF) that were used to develop inputs to the plant-level PRA model, consistent with the NRC guidance in DC/COL-ISG-20. The results of the fragility evaluation indicate that, in addition to the plant level HCLPF, the HCLPF values of the RXB structural components examined were also above 0.84g. For the reasons given above, the NRR staff concludes that the FSER accurately documents the staff's review and conclusions.