Staff Response to Taskings in the Executive Director for Operations Differing Profession Opinion Appeal Decision Concerning the NuScale Safety Evaluation

This enclosure responds to the taskings in the Executive Director for Operations (EDO) decision dated February 8, 2022,[1] on the Differing Professional Opinion (DPO) appeal concerning DPO-2020-004. The EDO taskings are in response to the first concern raised in the DPO appeal—that the NuScale reactor building design is incomplete, inadequate, and unsafe for the design-basis earthquake, primarily because no design modifications were made when demand forces exceeded capacity in several structural elements in the finite element analysis. The taskings thus relate to the staff's evaluation of the NuScale reactor building design in the U.S. Nuclear Regulatory Commission (NRC) staff's NuScale Final Safety Evaluation Report (FSER) Section 3.8.4, "Seismic Category I Structures," and, in part, Section 3.8.5, "Foundations."[2]

The EDO decision concluded that the basis for accepting NuScale's stress averaging approach for the reactor building design was not sufficiently documented. The EDO tasked the Office of Nuclear Reactor Regulation (NRR) to 1) document its evaluation of the stress averaging approach used in the NuScale design certification application (DCA), including, if necessary, updating the FSER for the NuScale DCA and assessing whether there are any impacts to the NuScale standard design approval (SDA)[3] issued in September 2020, and 2) evaluate and update guidance, or create knowledge management tools, as appropriate, on how to evaluate applications that use stress averaging for structural building design.

Tasking #1: Staff Evaluation of the NuScale Stress Averaging Approach

The EDO decision tasked the NRR staff to document its evaluation of the stress averaging approach used in the NuScale DCA, focusing on the averaging over the failure plane length that extends up to approximately four times the section thickness and in-plane shear demand over the full available section length. The EDO also directed the NRR staff to document the results of its evaluation and, if necessary, update the FSER for the NuScale DCA and assess whether there are any impacts to the NuScale SDA issued in September 2020.

NRR Staff Response

The NRR staff notes that the term "stress averaging" used in the EDO decision applies to metallic components such as steel structures. Since the concerns raised in the DPO appeal are related to reinforced concrete as opposed to steel, the NRR staff will use the applicable equivalent terminology, namely, "demand (force/moment) averaging" in its response consistent with the terminology used in the FSER and the DCA.

Unlike steel, which is a more homogeneous isotropic material, reinforced concrete is a composite material consisting of concrete and reinforcing steel and involves composite section

[1] Memorandum from D. Dorman to J. Ma, "Differing Professional Opinion Appeal Concerning DPO-2020-004," dated February 8, 2022, Agencywide Documents Access and Management System (ADAMS) Accession No. ML22021B617.
[2] U.S. NRC, FSER for the NuScale Standard Plant Design, Chapter 3, "Design of Structures, Systems, Components, and Equipment," dated August 28, 2020, ADAMS Accession No. ML20205L405.
[3] Letter from A. Bradford to Z. Rad, "Standard Design Approval for the NuScale Power Plant Based on the NuScale Standard Plant Design Certification Application," dated September 11, 2020, ADAMS Accession No. ML20247J564.

behavior and stress block assumptions to determine stresses in the two materials. Consequently, the stresses in the two materials do not have a direct linear correlation with demand forces/moments. Therefore, the averaging approach should be performed on demand forces/moments from the structural analyses used in the design code checks for strength design. It should be noted that the code specifies that design checks for strength design method be based on demand forces and moments, and not stresses. In the NuScale DCA Part 2, Tier 2, Appendix 3B, Section 3B.1.1.1, "Averaging Demand Forces and Moments,"[4] the applicant described its use of the demand averaging approach to assess localized demand exceedances over capacity (i.e., demand (D) to capacity (C) ratio exceeding 1.0).

The NRR staff reviewed the relevant documents referenced in the EDO decision and the information on the design of reinforced concrete structures described in the NuScale DCA as "Other Category I structures," namely, the reactor building (RXB) and control building (CRB) that used localized demand averaging in its design analysis. The NRR staff primarily focused on the RXB that was the subject of the DPO appeal decision. As noted in the NuScale DCA Part 2, Tier 2, Section 3.8.4, "Other Seismic Category I Structures,"[5] the applicant's code of record for the design of reinforced concrete seismic Category I structures is the American Concrete Institute code, ACI 349-06,[6] as modified by Regulatory Guide 1.142.[7]

The following discussion documents the technical basis for the acceptability of the demand averaging approach for addressing localized code exceedances (i.e., demand to capacity ratio, D/C, greater than 1.0) in certain reinforced concrete walls/slabs described in the NuScale DCA.

The NRR staff reviewed the NRC evaluation in FSER Chapter 3 and found it had discussed the basis for accepting the demand averaging approach as part of its documentation of the regulatory audit on the design of the NuScale seismic Category I structures. Specifically, FSER Section 3.8.5.4.3.6, "Foundation Basemat Analysis," states:

> *The staff found that the applicant's approach of averaging demand forces and moments over wall or slab sections are acceptable because it is a realistic engineering practice to consider adjacent finite elements' demand forces and moments when D/C ratio exceedances over a single finite element. The applicant also described this approach in DCA Part 2, Tier 2, Appendix 3B, Section 3B.1.1.1, "Averaging Demand Forces and Moments."*

Based on its review of the summary of design results in the DCA Part 2, Tier 2 sections that are referenced in item 5 below, the NRR staff noted that D/C exceedances calculated using conservative bounding demands in individual elements of the RXB and CRB were in the range 1.04 to 1.47. The maximum D/C exceedance of 1.47 occurred in the horizontal reinforcement at element 16296, which is part of the RXB stiffener wall at Grid Line 6, and the demand averaging was performed over two elements as described in DCA Part 2, Tier 2, Appendix 3B, Tables

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[4] NuScale Power, LLC, DCA, Part 2, Tier 2, Appendix 3B, "Design Reports and Critical Section Details," ADAMS Accession No. ML20224A491.
[5] NuScale Power, LLC, DCA, Part 2, Tier 2, Section 3.8.4, "Other Category I Structures," ADAMS Accession Nos. ML20224A488, ML20224A489.
[6] American Concrete Institute Code, ACI 349-06, "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary."
[7] U.S. NRC, Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," Revision 2, November 2001, ADAMS Accession No. ML013100274.

3B-11, “Summary of D/C Ratios for RXB Wall at Grid Line 6,” and 3B-12, “Element Averaging of Horizontal Reinforcement Exceedance for RXB Wall at Grid Line 6.” It should also be noted that most of the exceedances occurred in the stiffener wall or weir wall, which are not primary walls, due to structural discontinuities in the area of exceedance. In all cases of D/C exceedances, the D/C ratios were shown to meet the code acceptance criteria of D/C less than or equal to 1.0 after additional reinforcement was added or after localized demand averaging over a total of two or three immediately adjacent elements (including the element with exceedance). Therefore, the NRR staff has reasonable assurance that structural integrity of the RXB and CRB will be maintained.

The NRR staff finds the applicant’s approach of averaging demand forces and moments for performing code checks for strength design in areas of localized demand (D) to capacity (C) ratio exceedances (i.e., D/C greater than 1.0) to be a reasonable and acceptable practical approach based on the following seven items:

1) *Averaging is a reasonable approximation of localized redistribution of localized peak demands from elastic analyses:* In accordance with Section 8.3.1 of ACI 349-06, the applicant’s code of record, the demand forces and moments under design loads are developed by **linear elastic analyses** using finite element models. D/C ratio exceedances over 1.0 from elastic analyses are typically indicative of peak demands (stress concentration) due to the presence of structural discontinuities or irregularities, each of which results in a level of local cracking causing local stiffness reduction and thereby redistribution of forces/moments to adjacent areas. Another important potential reason for D/C exceedances is the use of a very conservative bounding/enveloping approach for developing maximum demands for code checks, as discussed in item 4 below. It is an accepted practice for design code checks to distribute demands (forces/moments) from linear elastic analysis to adjacent elements in areas of exceedances, and therefore, demand averaging **over immediately adjacent elements** is an approximate practical method to distribute demands for **localized exceedances**.

2) *Averaging is a reasonable limited approximation of localized component level structural behavior:* As described in DCA Part 2, Tier 2, Appendix 3B, Section 3B.2.2, “Design Approach -Walls,” the applicant performed individual **element-based** code design checks and only used averaging where exceedances existed. Section-based code design checks, over a relatively larger sectional area over the load path, are also done in practice when demands under design loads are obtained by linear elastic finite element analysis. Therefore, the applicant’s use of demand averaging over individual finite elements in localized areas corresponds to a very limited section-based check. This is based on the principle that imposed loads are resisted by the structure at the component or structural system level and not at the individual element level, and reinforced concrete has significant ability to redistribute element forces from regions of peak demands due to concrete cracking and deformation. Further, the basic principle followed in design checks is to verify equilibrium of internal forces and external loads over the sustainable load path, which occurs over a relatively larger section of the structural component (e.g., wall, slab) rather than over an individual localized element.

3) *Conservative uniform distribution of reinforcing steel based on maximum demands facilitates redistribution without failure:* As described in DCA Part 2, Tier 2, Section

3.7.2.1.1.3, "SASSI201,"[8] and DCA Part 2, Tier 2, Appendix 3B, Section 3B.2.2, the design configuration of the structural walls/slabs of the NuScale "Other Category I structures" is conservative because it is standardized; i.e., the **thicknesses and internal steel reinforcement of the primary walls/slabs are generally consistent (uniform) throughout each building wall/slab, and areas of lower forces/moments are not optimized for the local load**. The standardized design of the structural walls/slabs, including the use of good standard reinforcement detailing practices, allows for significant redistribution of forces/moments to adjacent areas without causing exceedances or potential for failure in those adjacent areas; hence, it is acceptable to approximate redistribution of demands by averaging over adjacent elements in areas of localized exceedances.

4) *NuScale used a conservative (not realistic) enveloping/bounding approach to develop maximum demands for design checks*: As described in DCA Part 2, Tier 2, Section 3.8.4.3, "Loads and Load Combinations," the final element demand forces/moments for design checks are obtained as the total of the maximum demand forces and moments for each element from the different finite element models. The total element demands are accordingly obtained as the sum of (1) the maximum static forces/moments from SAP2000 analyses for cracked, and uncracked, single and triple building models; and (2) the maximum seismic (dynamic) demand forces/moments from SASSI2010 analyses from cracked, and uncracked, single and triple building models. Thus, as described in DCA Part 2, Tier 2, Section 3.8.4.4.1, "Reactor Building Analysis," the envelope demand forces and moments from the uncracked and cracked condition are used regardless of the demand moments and the shear reaching their cracking limits. The purpose of the different finite element models used is to envelope the extracted demand forces and moments from the cracked and uncracked models from the static analysis and seismic analysis. These maximum demand forces and moments are then used in the design. DCA Part 2, Tier 2, Appendix 3B, Section 3B.2.1, "Design Report," states that the demand to capacity ratios for the RXB presented in DCA Part 2, Tier 2, Appendix 3B, Sections 3B.2.2, "Design Approach – Walls" through 3B.2.7, "NuScale Power Module Bay," represent bounding design values. Therefore, **an enveloping or bounding approach is used to determine maximum demands used in the element design checks,** which is conservative as discussed in FSER Section 3.8.4.4.4.1, "Analysis Procedures," but not realistic (or not representative) due to cracking and redistribution from stress concentration from discontinuities or onset of inelastic behavior in areas of localized exceedance. For example, the maximum of an element demand type may be obtained from the uncracked analysis whereas the representative demand may be from the cracked condition. Thus, it is acceptable to approximate more realistic (or representative) demands by averaging with adjacent elements in areas of localized exceedance.

5) *Averaging length based on immediately adjacent elements is reasonable for localized (single element) exceedances:* As described in the design reports and summary of design results for critical sections in DCA Part 2, Tier 2, Appendix 3B, the applicant performed **very localized** averaging of design forces/moments exceedances where the **exceedance is limited to a single element** in a given design zone/area of a wall or slab section. Further, the applicant's approach included averaging demands of only a

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[8] NuScale Power, LLC, DCA, Part 2, Tier 2, Section 3.7, "Seismic Design," ADAMS Accession No. ML20224A484.

total of two or three immediately adjacent elements (including the element with exceedance) in the appropriate direction for the demand being evaluated. This approach is described in (1) DCA Part 2, Tier 2, Appendix 3B, Section 3B.1.1.1, "Averaging Demand Forces and Moments" as part of the design report for "Other Category I structures" which include the RXB and the CRB; and (2) the summary of results for exceedances in DCA Part 2, Tier 2, Sections 3B.2.2.2, "Wall at Grid Line 3," 3B.2.2.3, "Wall at Grid Line 4," 3B.2.2.4, "Wall at Grid Line 6," 3B.2.3.2, "Slab at EL. 100'-0"," 3B.2.7.2, "Pool Wall," 3B.3.2.2, "Wall at Grid Line 4," 3B.3.2.3, "Wall at Grid Line A," 3B.3.3.2, "Slab EL. 100'-0"," and the corresponding tables referenced therein addressing the exceedances. The section length available for averaging could vary based on the demand type and available resisting failure plane in the load path. The NRR staff considered the typical element size of approximately 6 ft described in DCA Part 2, Tier 2, Section 3.7.2.1.1.3 and the wall/slab thickness of 5 ft for primary walls, 4 ft for stiffener walls, or 3 ft for floor slabs for "Other Category I structures," including the RXB described in DCA Part 2, Tier 2, Section 3.8.4.1.1, "Reactor Building," and Appendix 3B. It should be noted that actual element sizes are expected to be smaller than typical in areas of specific interest such as near discontinuities or irregularities. Based on these typical considerations, the NRR staff noted that the applicant used a maximum averaging length over a total of two to three immediately adjacent elements, including the exceedance element, which are minimal possible lengths for averaging and correspond with up to approximately 4 times the thickness immediately adjacent to and including the exceedance element. This approximate averaging length was determined from the highest approximate typical value of (number of elements averaged x element size / member thickness) calculated for slabs (2 x 6 ft / 3 ft = 4); for primary walls and weir wall (3 x 6 ft / 5 ft = 3.6 or 2 x 6 ft / 5ft = 2.4); and for stiffener wall sections which are not primary structural walls (2 x 6 ft / 4 ft = 3.0 or 3 x 6 ft / 4ft = 4.5). Therefore, the NRR staff finds that the applicant's use of an averaging length of up to approximately 4 times the wall/slab thickness is reasonable because the averaging performed over such length covers only immediately adjacent elements and it is feasible for the forces/moments to be redistributed over such length along the load path.

6) *NuScale appropriately addressed in-plane shear in two ways – by incorporating it in the main reinforcing steel design based on element demands, and by performing an additional gross structural wall check:* Regarding in-plane shear, as described in DCA Part 2, Tier 2, Appendix 3B, Section 3B.1.1, "Wall and Slab Design Methodology," and Section 3B.1.1.3, "Wall and Slab Design Approach," the design of main reinforcing steel in each direction on each face of a wall/slab is based on the combined effect of membrane tension forces, out-of-plane moments and in-plane shear; i.e., the area of reinforcing steel required for in-plane shear is also included in the total provided steel area of the vertical and horizontal reinforcement. As such, the reported element-based D/C ratios for the reinforcement includes the effect of net tension, including the in-plane shear effect carried by the reinforcement. Where lateral load transfer between orthogonal structural components occurs by bearing, this effect is captured in the reported element-based D/C ratio for horizontal compressive stress. Further, as an additional gross in-plane shear strength check of structural walls, the applicant's approach for calculating the nominal horizontal in-plane shear strength of structural walls, V_n, is consistent with the code-of-record Equation (21-7) in Section 21.7.4 and the related Section 11.10 of ACI 349-06. In code Equation (21-7), V_n is calculated based on A_{cv} which is the gross area of concrete bounded by web thickness and length of section, i.e., over the entire available length of the wall that is resisting in-plane shear. Section 2.1 "Code Notation," of ACI 349 defines the associated length, l_w, as the length

of the entire wall or length of segment of wall considered in the direction of shear force. Note that the length of a segment of wall applies only when the wall has opening(s) that create segmentation. Therefore, the in-plane shear demand force on the wall for comparison to the design strength is calculated along the entire available section length of the structural wall; i.e., the in-plane shear force demands for a design check are calculated as the sum of the in-plane shear element forces along the entire available horizontal section length of the structural wall because design lateral forces on structural walls are resisted by the in-plane shear strength of the entire available shear wall section that is part of the seismic resisting system. DCA Part 2, Tier 2, Table 3B-51, "Element Averaging of IP Shear Exceedance of Reactor Building Wall at Grid Line 3," provided an example of gross in-plane shear check for RXB Grid Line 3 weir wall and includes the top reentrant corner elements 4942 and 4951 with apparent element-level in-plane shear exceedances of the order of 3. As described in FSER Section 3.8.4.4.4.2, "Design Procedures," the NRC verified the applicant's in-plane shear check for the RXB walls during the seismic/structural audit and confirmed that in all cases the in-plane shear capacity of structural walls was greater than the in-plane shear demand.[9]

Specifically, the RXB wall for which the example gross in-plane shear check is shown in DCA Part 2, Tier 2, Table 3B-51 (mentioned above) is the same wall for which the D/C ratio exceedances are evaluated in DCA Part 2, Tier 2, Table 3B-3 "Summary of D/C Ratios for Reactor Building Wall at Grid Line 3" through Table 3B-7 "Summary of D/C Ratios for Reactor Building Wall at Grid Line 3 After Averaging Affected Elements," and the design summary provided in Table 3B-70 "Design Summary – Interior Weir Wall at Grid Line 3." As seen from DCA Part 2, Tier 2, Figures 3B-10, 3B-11, 3B-12, and 3.8.4-1, and Table 3B-70, this is a 5 ft thick, short, heavily reinforced well-detailed interior weir wall spanning horizontally (approximately 34 ft) in the north-south direction along grid line 3, interfacing with the east-west walls and pilasters along grid lines C and D, and running vertically 26 ft between elevations 24 ft and 50 ft. This weir wall serves as a partition providing compartmentalization between the reactor pool and spent fuel pool and is not necessarily intended to be part of the seismic resisting system. As seen from DCA Part 2, Tier 2, Table 3B-3 includes the only two elements (4951 and 4942) with exceedances out of all of the 84 wall elements that were checked. Element 4951 has D/C ratios of 1.44 and 1.40, respectively, for horizontal and vertical reinforcement and element 4942 has D/C ratio of 1.04 for horizontal compression. As explained in the previous paragraph, these D/C ratio exceedances include the effect of in-plane shear in the reinforcement. Elements 4951 and 4942 show exceedances because they are located at the reentrant corners on the top free surface of the wall where it interfaces with orthogonal walls along grid lines C (north end element 4951) and D (south end element 4942) where stress concentrations are expected. Load transfer occurs at these locations by the orthogonal wall pulling away on the north end (element 4951) and by bearing on the south end (element 4942), or vice versa depending on the direction of seismic motion. While such localized exceedances occurring at interfacing reentrant corners near the top free surface of the wall may result in some localized cracking, crushing, or potential local yielding, it will not cause a failure of the wall. As stated previously, there were no other elements with demand exceedances for the weir wall. As described in DCA Part 2, Tier 2, Tables 3B-4 through 3B-7, these D/C ratios in

[9] Memorandum from M. Vera to S. Lee, "Summary Report of Regulatory Audit of Design Documents for NuScale Design Certification Part 2, Tier 2, Sections 3.7 and 3.8," dated May 14, 2019, ADAMS Accession No. ML19098A162.

elements 4951 and 4942 were shown to be less than or equal to 1.0 by averaging over 2 (for element 4942) to 3 (for element 4951) immediately adjacent elements including the element with exceedance. From Table 3B-51, the maximum element size at the reentrant corners of the wall is 46.5 in (3.875 ft); therefore, the averaging in this case was performed over a maximum length of 2.3 [3 x 3.875 ft / 5 ft] times the thickness of the wall. As explained in the previous paragraph, elements 4942 and 4951 were included in the additional gross in-plane shear check for structural walls that was shown in Table 3B-51 to be performed over the entire wall horizontal section (not by element) and to meet the acceptance criteria consistent with the provisions of the ACI 349 code. Thus, there is reasonable assurance the structural integrity of the RXB weir wall along grid line 3 will be maintained.

7) *Applicant's approach includes design modifications when averaging approach is determined to be inappropriate:* In DCA Part 2, Tier 2, Appendix 3B, Section 3B.2.2, the applicant stated that its design approach evaluates each region where individual elements exceed design requirements. If the design approach of averaging the results of adjacent elements to obtain more realistic forces/moments for design is inappropriate for the location or does not produce acceptable results, then additional reinforcement is added to increase section capacity. For example, DCA Part 2, Tier 2, Appendix 3B, Section 3B.3.2.2 describes that the CRB wall at grid line 4, which had an out-of-plane shear exceedance, had additional #6 stirrup reinforcement added to satisfy the demand. Therefore, the applicant's approach does include making design modifications in regions of exceedances when the averaging approach is inappropriate or does not result in meeting code strength requirements.

With regard to the statement in the EDO DPO appeal decision that "[i]n ANSI/AISC N690-18, stress averaging is limited to no longer than twice the section thickness," the NRR staff notes that this requirement in the code is contained in, and has specific applicability only to, the provisions in the new Appendix N9, "Steel-plate Composite (SC) Walls" of ANSI/AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities,"[10] and does not have applicability to steel or reinforced concrete structures. The ANSI/AISC N690-18 specification has no such design and analysis requirements for steel structures, which is its primary scope, and the ACI 349-06 code has no such requirements for reinforced concrete structures. SC construction is a relatively new composite concept consisting of plain concrete sandwiched between two steel faceplates. Reinforced concrete has superior ductility characteristics compared to SC construction, and therefore has better ability to redistribute forces and moments through cracking, even prior to reinforcing steel yielding, as well as by yielding; therefore, localized averaging of demands may be performed for reinforced concrete structures over a length that is significantly larger than 2 times the thickness recommended for SC structures.

For the reasons listed above, the NRR staff finds that the demand averaging approach used by the applicant to resolve localized D/C ratio exceedances is a reasonable and acceptable method to approximate more realistic structural behavior and shows that the code acceptance criteria are met in such areas; therefore, there is no impact on the conclusions in FSER Section 3.8.4.6 that the design of the NuScale "Other Seismic Category I structures" (namely, the RXB

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[10] 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.

and CRB) is acceptable and meets the relevant requirements described in FSER Section 3.8.4.3. The NRR staff thus concludes there is reasonable assurance of adequate protection and that the applicant's approach of demand averaging has no impact on the NRC staff's conclusions on the NuScale standard plant design. Accordingly, the NRR staff concludes that there is no impact on the NuScale SDA and that no changes to the DCA are needed.

Additionally, the NRR staff would like to provide the following remarks regarding the review that was conducted by the NRC staff for Other Category I structures in support of its regulatory finding and conclusions in FSER Sections 3.8.4 and 3.8.5.

(a) As stated in FSER Section 3.8.4.4, the NRC staff conducted its review of the structural analysis and design of "Other Seismic Category I structures" and documented its findings in accordance with the guidance in Section 3.8.4 of the Design-Specific Review Standard (DSRS) for the NuScale Small Modular Reactor (SMR) Design.[11] Consistent with DSRS Section 3.8.4, the NRC staff reviewed (a) the description of the structures, (b) applicable codes, standards, and specifications, (c) loads and load combinations, (d) design and analysis procedures, (e) structural acceptance criteria, (f) materials, quality control, and special construction techniques, (g) testing and inservice surveillance requirements, and (h) the applicable combined license information items. The staff documented its evaluation in FSER Sections 3.8.4 and 3.8.5 based on the DSRS acceptance criteria. While not explicitly tied to the staff's evaluation of localized demand averaging, most of the technical bases discussed in items 1 through 7 above are directly or indirectly addressed in the related FSER Sections 3.7.2, 3.8.4, and 3.8.5 where the NRC staff documented different aspects of its review.

(b) With regard to addressing code exceedances, the review procedures for structural acceptance criteria in DSRS Section 3.8.4, Subsection III.7, states in part:

> *The reviewer compares the limits on allowable stresses and strains in the concrete, reinforcement, structural steel, etc., with the corresponding allowable stresses specified in Subsection II.5 of this SRP section [which refers to ACI 349 with additional guidance in Regulatory Guide 1.142 for concrete structures]. If the applicant proposes to exceed some of these limits for some of the load combinations and at some localized points on the structure, the reviewer evaluates the justification provided to show that structural integrity will not be affected. If the reviewer determines such justification to be inadequate, the proposed deviations are identified and transmitted to the applicant with a request for adequate justification and bases.*

Further, DSRS Section 3.8.4, Subsection I.F, states that "the structural audit is conducted in accordance with the provisions of Appendix B of this DSRS section." The objectives of the structural audit are an integral part of the review process and include verifying the adequacy of the applicant's implementation of its structural design criteria and confirming the acceptability of key structural design calculations. Further, DSRS Section 3.8.4, subsection I.4.D, directs the staff to review the applicant's design report containing information specified by Appendix C to DSRS 3.8.4 regarding the applicant's design implementation and quantitative summary of design results for seismic Category I

[11] U.S. NRC, DSRS for NuScale SMR Design, Section 3.8.4, "Other Category I Structures," July 2016, ADAMS Accession No. ML15355A444.

structures. As stated in Appendix C to DSRS 3.8.4, the primary objective of the design report is to provide the reviewer with more specific design and construction information than that contained in the main body of the FSAR, and to assist the reviewer in planning and conducting the structural audit. Accordingly, the applicant provided its design report and summary of results for critical sections for seismic Category I structures in DCA Part 2, Tier 2, Appendix 3B.

Consistent with the related DSRS review procedures, the NRC staff documented in FSER Sections 3.8.4.4.4.2 and 3.8.5.4.3.6 its review and verification of the design report and summary of implementation results described in DCA Part 2, Tier 2, Appendix 3B and the staff's related structural audit. The NRC staff concluded that the applicant's summary of demand and capacity evaluations demonstrated that all critical sections have sufficient capacity to withstand the design-basis demands. Regarding the demand force/moment averaging approach used by the applicant, consistent with the guidance in DSRS Section 3.8.4, Subsection III.7, the NRC staff reviewed the issue during its structural audit in December 2018 and requested additional information and justification as part of Request for Additional Information (RAI) 03.08.04-26. The applicant provided responses to this RAI.[12,13] As a result, the applicant made changes to its design calculations and supplemented or modified the information in the design report and summary of results in DCA Part 2, Tier 2, Appendix 3B. In FSER Section 3.8.5.4.3.6, the NRC staff documented its basis for accepting the demand (force/moment) averaging approach reviewed as part of its regulatory audit as follows:

> *The staff found that the applicant's approach of averaging demand forces and moments over wall or slab sections are acceptable because it is a realistic engineering practice to consider adjacent finite elements' demand forces and moments when D/C ratio exceedances over a single finite element. The applicant also described this approach in DCA Part 2, Tier 2, Appendix 3B, Section 3B.1.1.1, "Averaging Demand Forces and Moments."*

This FSER statement captures the primary basis for the NRC staff accepting the applicant's approach: that averaging is an acceptable approximation of more realistic demands when the exceedance is in a **single finite element (localized)** of the design zone and consideration for **averaging is limited only to adjacent elements**. As discussed above, the NRC staff conducted an adequate review of the issue consistent with the DSRS guidance, and the documentation of information in DCA Part 2, Tier 2, Appendix 3B is sufficient.

Tasking #2: Evaluation of Existing Guidance

The EDO decision tasked the NRR staff to evaluate and update guidance, or create knowledge management tools, as appropriate, on how to evaluate applications that use stress averaging for structural building design.

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[12] NuScale Power, LLC, Letter No. RAIO-0419-65223 (Docket No. 52-048) from Z. Rad to U.S. NRC Document Control Desk, "NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 201 (eRAI No. 8975 – 03.08.04-26) on the NuScale Design Certification Application," dated April 15, 2019, ADAMS Accession No. ML19105B290.
[13] NuScale Power, LLC, Letter No. RAIO-1017-56791 (Docket No. 52-048) from Z. Rad to U.S. NRC Document Control Desk, "NuScale Power, LLC Response to NRC Request for Additional Information No. 201 (eRAI No. 8975) on the NuScale Design Certification Application," dated October 24, 2017, ADAMS Accession No. ML17297B940.

NRR Staff Response

The guidance in NuScale DSRS Section 3.8.4, Subsection III.7, and NUREG-0800, Standard Review Plan (SRP), Section 3.8.4[14], Subsection III.5, review procedures for structural acceptance criteria, states in part:

> *<u>Structural Acceptance Criteria</u>. The reviewer compares the limits on allowable stresses and strains in the concrete, reinforcement, structural steel, etc., with the corresponding allowable stresses specified in Subsection II.5 of this [DSRS/SRP] section. If the applicant proposes to exceed some of these limits for some of the load combinations and at some localized points on the structure, the reviewer evaluates the justification provided to show that structural integrity will not be affected. If the reviewer determines such justification to be inadequate, the proposed deviations are identified and transmitted to the applicant with a request for adequate justification and bases.*

The NRR staff finds that the DSRS and the SRP currently contain sufficient guidance for resolution of code check exceedances while allowing for flexibilities to review an applicant-specific approach to meeting the acceptance criteria. Since the structural analysis and design process involves making appropriate modeling idealizations, assumptions, approximations and professional judgements, there are many ways in which an issue can be addressed, and force/moment averaging is only one way of addressing code exceedances. Therefore, the specific approach used by an applicant for resolving such issues as localized code acceptance criteria exceedances and its significance should be left to the discretion and professional judgement of the structural analyst and licensed design professional used by the applicant, and the NRC staff should focus its review on the reasonableness of the applicant's justification on a case-by-case basis, which is provided for in the current guidance.

As discussed in detail in the response to Tasking #1, the NRC staff conducted a sufficient and adequate structural audit and review of the design of Other Seismic Category I structures, consistent with the guidance in DSRS Section 3.8.4. Note that the corresponding guidance in NUREG-0800 SRP Section 3.8.4 is also the same. The applicant made changes to its design calculations and revised the design report in response to the NRC staff's audit questions, feedback, and requests for additional information. Therefore, the NRR staff does not recommend any updates to the existing guidance to evaluate use of demand averaging. Since high-level guidance for case-by-case evaluation of localized code acceptance limit exceedances exists in the current DSRS/SRP, the NRR staff's assessment is consistent with the policy direction in NRR Office Instruction LIC-200[15] that the SRP specifies the high-level acceptance criteria for meeting the applicable regulation and describes acceptable methods the NRC staff may use in order to make a finding. The NRC staff plans to develop knowledge management tools to highlight the findings detailed in this enclosure and document appropriate methods for demand averaging in structural analysis.

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[14] U.S. NRC, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, Section 3.8.4, "Other Seismic Category I Structures," Revision 4, September 2013, ADAMS Accession No. ML13198A258.
[15] U.S. NRC, NRR Office Instruction LIC-200, "Maintaining and Updating the Standard Review Plan," Revision 2, dated March 6, 2020, ADAMS Accession No. ML19234A226.