Prioritization of Codes and Standards Gaps in Enabling Rapid, High-Volume Deployable Microreactors

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Revision 0

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EXECUTIVE SUMMARY

Microreactors offer the potential to expand energy access for remote communities and critical industries through features such as factory manufacturing, autonomous operation, and rapid transportability. However, realizing this potential at scale requires that the codes and standards (C&S) governing nuclear design, construction, and licensing keep pace with these novel technologies. Current C&S were developed primarily for large light water reactors and may not be directly applicable to microreactors, presenting a barrier to deployment.

This report is the third phase of a multiphase effort to identify, evaluate, and prioritize C&S gaps relevant to microreactor deployment. Prior phases established the regulatory and industry context through a background whitepaper and structured engagement with microreactor designers to identify challenges. Building on that foundation, this report identifies specific C&S gaps and develops a draft prioritization matrix to guide future Department of Energy (DOE) action.

The six challenge areas, and their associated gaps, are (1) pressure boundary and ASME code applicability, (2) graded design life and inspection, (3) materials qualification, (4) reactor transportation, (5) unique deployment configurations, and (6) advanced modeling and validation. A draft prioritization matrix was developed that evaluates each gap area against four criteria: applicability across microreactor designs, impact on deployment, need for DOE action, and value of DOE action. This prioritization matrix is a living document. As microreactor designs mature and additional designer engagement is conducted, gaps will be refined and new gaps may be added. The matrix will be updated in subsequent project phases and will ultimately inform a plan of action and recommendations for how DOE and the national laboratories can most effectively support resolution of these C&S barriers to enable timely, high-volume microreactor deployment. Importantly, most of this report was written before the NRC's release of proposed rule, Title 10 of the *Code of Federal Regulations* Part 57, "Licensing Requirements for Microreactors and Other Reactors with Comparable Risk Profiles" in April 2026. This report will be updated in the future to account for the flexibility the new rule may provide designers.

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ACRONYMS

ARCSC	Advanced Reactors Codes and Standards Collaborative
ASME	American Society of Mechanical Engineers
BPVC	Boiler and Pressure Vessel Code
C&S	Codes and Standards
DOE	U.S. Department of Energy
HTGR	high-temperature gas-cooled reactor
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
ISI	in-service inspection
IST	in-service testing
LWR	light water reactor
MOOSE	Multiphysics Object Oriented Simulation Environment
MRP	Microreactor Program
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
RIM	Reliability Integrity Management
SSC	structures, systems, and components
SDO	standards development organization
SME	subject-matter expert
TRISO	tristructural-isotropic (fuel)

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1. INTRODUCTION

Microreactors are anticipated to broaden energy availability and lower costs for many critical industries and geographically remote communities. Realizing this potential at scale will require high-volume deployment enabled by features such as assembly-line manufacturing, factory fueling, rapid transportation, and autonomous or remote operation. These characteristics, however, represent significant departures not only from the existing nuclear fleet but also from other advanced reactor designs currently under development. The codes and standards (C&S) that govern nuclear design, construction, licensing, and operation were written primarily with large light water reactors (LWRs) in mind and may not be applicable—or may present unintended barriers—when applied to microreactor technologies. Therefore, identifying and resolving these C&S gaps is a prerequisite for enabling the timely and cost-effective deployment of microreactors.

This report is part of a multiphase effort sponsored by the U.S. Department of Energy (DOE) Microreactor Program (MRP) to systematically identify, evaluate, and prioritize C&S gaps relevant to microreactor deployment and develop actionable recommendations for how DOE can support the resolution of those gaps.

In the first phase, a whitepaper was developed, which provided background on the Nuclear Regulatory Commission (NRC) C&S endorsement process, an overview of the state of the microreactor industry, a characterization of microreactor technologies, and a preliminary review of publicly identified challenges related to microreactor C&S [1]. A key finding of that review was that the industry has focused on identifying and addressing C&S gaps for advanced reactors but not specifically microreactors [2, 3]. As such, the public information on microreactor C&S gaps is limited, emphasizing the need for microreactor-specific gap exploration.

In the second phase, the project team conducted structured engagement with a range of microreactor experts, including designers, consultants, and other stakeholders to solicit input on existing challenges related to microreactor C&S [4]. This external industry engagement identified six recurring technical themes where current C&S may present barriers to deployment.

Building on the challenges of the prior phases, this report develops a list of gaps in microreactor C&S and a draft prioritization matrix. This prioritization matrix will be updated in the next phases of the report and in its final form will inform a future plan of action and recommendations for how DOE can support the resolution of these C&S gaps. As such, the prioritization aims to identify areas that should be considered short-term and long-term priorities as well as areas for high/low impact.

The prioritization gaps presented here were identified before the U.S. NRC released its proposed rule for Title 10 of the *Code of Federal Regulations* (10 CFR) Part 57, "Licensing Requirements for Microreactors and Other Reactors with Comparable Risk Profiles" in April 2026. Some of these gaps may be addressed using Part 57, but this will be evaluated in the later phases of this project, after the U.S. NRC releases the final rule.

2. BACKGROUND

Microreactors are most commonly defined according to their power capacity (e.g., <50MWe according to the INL/GAIN taxonomic guidance [5]); however, a more appropriate definition is through the several characteristics of microreactors (besides power capacity) that differ from their larger counterparts. The following lists the key features of microreactors that differentiate them from other traditional and advanced reactor designs:

- Small source term
- Flexibly sited
- Factory produced and tested
- Mobile and transportable
- Longer refueling cycles
- Rapidly deployed
- Autonomous or semi-autonomous operation
- Short operational lifetimes
- Minimal site preparation
- Microgrid operation.

The uniqueness of the design and application of microreactors also presents a challenge in the use and incorporation of C&S into the design of these reactors. The standards design organizations (SDOs) are making changes to the nuclear industry C&S to be more applicable to advanced reactor applications, but some gaps still exist for microreactor-type designs.

Six microreactor design teams from the industry were interviewed in the previous phase of this project. In addition to these designers, two microreactor design teams at Idaho National Laboratory (e.g., MARVEL) and microreactor subject-matter experts (SMEs) from other national labs were also interviewed. The upcoming microreactor designs are vastly different from the LWRs driving the C&S that currently exist. The differences, including alternative coolants, operating pressure regimes, fuel forms, and passive safety strategies, identify areas where existing C&S requirements may require clarification, reinterpretation, or risk-informed application.

3. GAP IDENTIFICATION

The literature review and industry engagement revealed that the existing set of C&S may present challenges to designing, construction, licensing, and operating microreactors. Here, these challenges are discussed in greater detail and specific gaps in the C&S are identified. There are a few caveats to note here:

1. Most of the reactor designers have not yet completed their designs and many of the discussions were limited to the core and primary loop design. Some designs utilize non-traditional installation strategies, such as placing reactors in deep boreholes, which presents gaps related to deployment. Therefore, the list of gaps identified in this report is not comprehensive and should be expanded and updated as microreactor designs progress toward deployment.
2. Because of the proprietary nature of the designs, the discussions were fairly high-level and identified six challenge areas. The project team utilized the interview data and subject-matter expertise to conduct deeper dives into these challenge areas and identify more tangible gaps in C&S.

3.1. Pressure Boundary and ASME Code Applicability

Industry engagement identified challenges associated with pressure boundary and ASME code applicability for certain microreactor designs. Many designs do not rely on pressure retention as the primary radiological containment function, and some configurations operate with equalized internal and external pressures.

Traditional application of ASME codes for pressure boundary design is structured around pressure-driven and time-dependent failure modes. ASME Section III and ASME Section VIII provide some applicability for low pressure conditions, primarily tanks, and could have limited applicability to those microreactor designs that operate at lower pressures.

Microreactors that operate in much higher temperature regions must address the potential for damage due to creep. As discussed in Section 3.3 of this report, ASME Section III, Division 5 provides additional operating temperatures for materials with limitations on time. However, this requires additional analysis to ensure proper applicability to the design. ASME Section III, Division 5 identifies a design-by-analysis approach that can justify applying the material, and in at least one instance, designers stated that a design-by-analysis approach was applied for a specific configuration of a component.

Many microreactor designs lean on advanced component design and manufacturing (e.g., compact heat exchangers, especially diffusion-bonded or printed-circuit heat exchangers and other microchannel recuperators that deliver the heat-transfer area in a small, rugged block). These types of nuclear-class components would be built around design-by-rule formulas for familiar shapes (e.g., shells, heads, nozzles, tubes, weld details). A monolithic diffusion-bonded microchannel block does not behave like a classic vessel or a tube bundle, and the code coverage is often incomplete or indirect; therefore, there is a need to apply a design-by-analysis approach and qualification testing to make an acceptable safety case.

Gap 1.1 – ASME Section III, Division 5 Design by Analysis

This gap seems to stem from two reasons: (1) some of the current microreactor designs may have preceded the addition of a design-by-analysis section in ASME Section III, Division 5 and (2) a better understanding of the challenges following this standard's requirements is needed. Addressing the gap will entail soliciting additional information with more detailed examples of challenges experienced by the designers. Guidance developed by an SDO or DOE can be beneficial in providing a consistent and generally accepted approach to implementing the design-by-analysis requirements.

3.2. Graded Design Life and Inspection

Industry engagement highlighted potential misalignment between microreactor operational concepts and existing inspection and service-life frameworks. Operational lifetimes on the order of approximately 3–10 years and are intended for replacement rather than refurbishment contrasts with current light water reactor lifetimes that assume multidecade service life.

In this section, *design life* refers to the operational life for the microreactor or the structures, systems, and components (SSCs). The overall operating life of a microreactor may be less than 10 years without a need for refueling or performance of major maintenance. The design of the microreactor may provide for a complete replacement, or major component replacement, at the end of the expected operating life. Therefore, focus on operating lifetimes is implemented in the following assessment of information provided by the engagement with industry.

10 CFR Parts 50 and 52 contain requirements for maintaining and inspecting nuclear facilities with two key requirements being:

- 10 CFR 50.34(b)(6)(iv) requires that the final safety analysis report shall include plans for conducting normal operations, including maintenance, surveillance, and periodic testing of SSCs.
- 10 CFR 52.79(a)(29)(i) requires that the application for a combined license includes plans for conducting normal operations, including maintenance, surveillance, and periodic testing of SSCs.

LWR operators comply with these requirements through implementation of an Inservice Inspection (ISI) Program and Inservice Testing (IST) Program in accordance with the requirements of 10 CFR 50.55a, which incorporates by reference ASME Code Section III, Section XI, and ASME Operation and Maintenance Code. Since these codes are not applicable to non-LWRs, the NRC staff issued Regulatory Guide 1.246, Acceptability of ASME Code, Section XI, Division 2, "'Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants,' For Non-Light Water Reactors" to provide an acceptable method for non-LWRs to develop and implement an ISI Program (a similar regulatory guide is in development for IST Programs).

Industry engagement highlighted the challenges of a shorter operational timeframe of microreactors and limited access to perform inspection and testing of SSCs. It is not only the challenge to perform these activities—the shorter operational timeframe and associated design life of the reactor may even preclude the need for performing certain inspections and tests that are required for multidecade operation.

ASME Section XI, Division 2 provides a process for developing a condition monitoring program, referred to as a Reliability Integrity Management Program, that is similar to a traditional ISI Program implemented at LWRs. However, the RIM Program uses practices such as monitoring and non-destructive examination to maintain the reliability of SSCs specifically determined from the degradation mechanisms that may exist through the life of the plant.

Because the type and periodicity of monitoring and inspections are based on the known and potential degradation mechanisms that SSCs may experience, the limitations for performance are less oriented around a fixed periodicity in a traditional ISI Program and more toward the SSC design and the operating conditions for the SSC. Therefore, if it can be shown that an SSC will perform its function through its design life without specific inspections or tests, then this will be reflected in the RIM Program. It is noted that it is unlikely there is a complete exclusion of any type of monitoring or examination, and a design will likely have some means of continuous, or online, monitoring of an SSC.

Gap 2.1 – Inspections and condition monitoring

Several designers indicated the unique configurations and applications of some microreactors present challenges with the performance of ISI and condition monitoring of the reactor and supporting systems. The industry has made progress in developing techniques and standards to perform inspections and continuous condition monitoring. This gap represents an opportunity to create an industry workshop or develop a document that helps communicate to the industry how current C&S can be applied and develop an industry position for application of some new continuous monitoring technologies.

3.3. Materials Qualification

Many materials qualifications in the nuclear industry have been performed to support the current LWR technologies. Non-LWRs typically operate at significantly higher temperatures. In many designs, the materials will operate in temperature ranges corresponding to the creep regime in which deformation can occur when a stress is applied. Benchmarking data, to support material qualification at these temperatures, until recently, has been limited or non-existent.

The primary means of qualifying a material is through ASME Boiler and Pressure Vessel Code (BPVC), also commonly referred to as ASME. ASME Section III governs the construction of vessels, piping, pumps, valves, supports, and core support structures for nuclear facilities. In response to having provided the code for LWRs, ASME developed ASME Section III, Division 5 to apply to high-temperature reactor systems used in advanced reactor designs, such as microreactors.

Industry engagement identified materials qualification and benchmarking as a key issue for microreactor deployment. It is not clear to what extent the microreactor designers are able to apply the recent update (2025 Edition) to ASME Section III, Division 5. The update includes additional rules for applying materials at elevated temperatures with provisions the designer must demonstrate as a result of the potential for significant creep effects.

ASME Section III, Division 5, Subsection HBB-II-6120 provides temperature and time limits for materials to be used in high-temperature regions. Time limits vary, but several materials are shown for up to 300,000 hours and, when other criteria are met, can provide the necessary operating design life for some materials.

Use of these materials must not only comply with the requirements of ASME Section III, Division 5, but also additional condition monitoring is to be performed to address other operating conditions that can cause degradation and were not addressed by the material qualification process [6]. The use of condition monitoring is a key attribute for a regulatory approach to accelerating the deployment of new material in advanced reactor designs [7].

Gap 3.1 – Deployment of materials in high operating temperature environments

This gap is twofold: (1) re-engagement with microreactor designers to confirm and further define gaps when applying the 2025 Edition of ASME Section III, Division 5 and (2) exploring the potential for implementing an approach to accelerate the deployment and use of a material for high-temperature applications.

The qualification and use of materials is not limited to only metallics but also applies to non-metallic materials such as graphite. ASME has been making progress with the rules in Section III, but there are portions of the code that are still in the course of preparation, such as ASME Section III, Division 5, Subsection HHA-3144. As pointed out in Ref. [8], ASME BPVC Section III, Division 5 required extensive graphite materials-data-sheet information, including oxidation and neutron-irradiation effects, and no nuclear graphite grades are currently code qualified. It also showed that the timeline for material qualification was long because the irradiation program could extend for many years, and qualification costs were substantial.

Gap 3.2 – Qualification of non-metallics for use in microreactor operating environments

Understanding the status of industry activities for the qualification of graphite materials needs to be gained to identify what gaps are present and determine if industry action needs to be taken or if current activities are sufficient to support the deployment of microreactors.

3.4. Reactor Transportation

Industry engagement identified transportation and packaging analysis as a significant consideration for microreactor deployment. Transportability is integral to many microreactor concepts, including the transportation of a reactor with both fresh and used fuel. Current framework limitations include lack of integration between transportation safety analysis and reactor safety and design decisions and limited clarity on applying risk-informed approaches to use existing certified packages. Designers noted that these gaps increase analytical burden and regulatory uncertainty, create risk of late-stage redesign if transportation is not addressed early, and contribute to added cost and schedule exposure.

10 CFR Part 71, "Packaging and Transportation of Radioactive Material" establishes "requirements for packaging, preparation for shipment, and transportation of licensed material; and procedures and standards for NRC approval of packaging and shipping procedures for fissile material and for a quantity of other licensed material in excess of a Type A quantity." Essentially, this classifies packages as type A or type B, based on the quantity of radioactive material and sets requirements for each package type, with type B being the higher limit with stricter requirements. Microreactor transportation will most likely fall into the type B category, as any amount of low-power testing generates enough plutonium to exceed type A levels.

Gap 4.1 – Lack of type C container standard in the United States limits the ability to transport microreactors by air

The type A and type B limits and requirements apply to ground transportation but not air transportation. Internationally, the International Atomic Energy Agency (IAEA) SSR-6 provides packaging and transportation requirements, which parallels 10 CFR Part 71. The most significant difference between these two regulations is that the IAEA defined a type C package, which is suitable for air transportation. There is no type C package in the United States, which may limit the ability to transport and deploy microreactors by air.

Gap 4.2 – Lack of high-temperature material standard for transportation packaging

Regulation 10 CFR Part 71 mandates that packages are designed according to applicable C&S. For nuclear applications, this is typically ASME Section VIII, Division 3 or ASME Section III, Subsection NB-3000, depending on designer choice. These standards govern the structural and pressure integrity of transportation packages. However, current ASME codes predominantly cover stainless and carbon steels, which may not be suitable for microreactor vessels that operate at higher temperatures than traditional reactor designs. This presents a gap for designers who must demonstrate compliance with packaging standards using materials that are not yet well characterized within the existing code framework.

Gap 4.3 – Limited material coverage in ASME strain-based failure criteria restricts designer ability to optimize transportation package design

A related gap exists in strain-based failure criteria within ASME codes. Strain-based criteria allow for reduced safety factors and better exploitation of material capacity, which is advantageous for transportation package design. However, only a limited set of materials are currently covered under these criteria, and designers face challenges in providing sufficient material data to satisfy regulatory requirements. To date, designers have not invested heavily in the material testing necessary to expand this coverage.

3.5. Unique Deployment Configurations

The size and applications being considered by microreactor designers involve unique design features and configurations, such as below grade deployment. Some designers indicated that there are non-nuclear standards that can be utilized, but uncertainty exists on the use of commercial and other industry standards for safety-related components. This introduces regulatory uncertainty and increased design iterations to reconcile code conflicts. Challenges to meeting ISI and operational requirements result from these unique applications as well, which is addressed in Section 3.2 of this report.

This challenge does not align with identifying specific C&S to be created or if existing C&S should be revised, but it relates to how an approved code or standard for non-nuclear applications (also referred to as commercial C&S) can be applied to nuclear reactors. At the NRC Standards Forum, Part 2, in January 2026, a session on NRC's perspective on the use of commercial C&S was presented [9]. The NRC indicated that current regulations allow the use of commercial C&S when it can be demonstrated that the requirements are met for issuance of a license. Two examples where a commercial code or standard was requested for safety-related SSCs were presented and discussed at the forum.

Gap 5.1 – Use of commercial C&S

Several designers expressed limited ability to apply the typical nuclear industry design and construction codes and indicated that commercial C&S can be a good alternative. The NRC has approved requests for advanced reactor designs (at the preliminary design phase) to use a commercial C&S for SSCs categorized as safety related and for SSCs categorized as non-safety with special treatment. This gap represents an opportunity for industry to identify multiple C&S that can readily apply to several microreactors and developing an approach and basis for more broad approval rather than a per design basis.

3.6. Advanced Modeling and Validation

Industry engagement highlighted increasing reliance on physics-based modeling and simulation to support microreactor design, safety analysis, operational monitoring, and licensing, including the use of advanced multiphysics tools to inform performance assessments. However, designers identified validation and acceptance gaps, including limited benchmark data for coupled multiphysics codes applied to microreactor geometries, lack of clearly defined acceptance criteria for digital monitoring and model-informed tools, and uncertainty in safety versus non-safety classification of digital and analytical assets [10]. These gaps contribute to increased review scrutiny and requests for additional validation data, licensing uncertainty associated with model credibility, and potential schedule impacts tied to tool qualification and regulatory acceptance. Ongoing collaboration with national laboratories on advanced modeling platforms, including the Multiphysics Object Oriented Simulation Environment (MOOSE), was identified as a promising pathway toward increased confidence and acceptance [11, 12].

Gap 6.1 – Lack of guidance on the use of digital twins

Industry feedback suggested that advanced modeling and simulation have now become an integral part of microreactor design, safety, and licensing strategy. Examples of using a range of existing software based on INL's MOOSE framework were provided, including Bison, Griffin, Cardinal, Relap-7, and Sockeye. The challenges with adopting and utilizing these applications include the lack of benchmark data, lack of clear guidance on the use of digital twin technology and associated model-informed software based on multiphysics codes, and the need to provide design margins to compensate for the associated uncertainties.

Given the novelty of digital twins for nuclear applications, guidance may need to be developed on their safety categorization as well as developing acceptance criteria (e.g., quality assurance). This involves reaching back out to the designers to get a better understanding of their challenges in using digital twins as well as relevant SMEs and SDOs.

Gap 6.2 – Lack of guidance on use of autonomous systems

Safety classification of digital instrumentation and control and analytical assets is important for licensing. Under 10 CFR 50.54, anything affecting reactivity or power level must be manipulated with a licensed operator present, and 10 CFR 55.4 ties technical specifications to the safety analysis. Oak Ridge National Laboratory (ORNL) identified several likely licensing obstacles for highly autonomous microreactors, including staffing, control manipulation, licensed operator requirements, technical specifications, cybersecurity, and notifications [13]. Further complicating matters, autonomous or remote-control systems may require reclassification of otherwise non-safety-critical components as safety-critical, introducing additional uncertainty. Current cybersecurity guidance is limited for addressing these reclassifications.

Given the novelty of autonomous operations for microreactors, guidance may need to be developed on their safety categorization as well as developing acceptance criteria (e.g., quality assurance). This involves reaching back out to the designers to get a better understanding of their challenges in developing autonomous systems as well as relevant SMEs and SDOs.

3.7. Other Codes and Standards

Focus on the technical subjects of the previous sections results from common topics mentioned by the designers participating in the interviews. A review of the interview data identified additional subjects that, in the opinion of the report authors, should be highlighted for additional consideration as a gap that, when addressed, can provide benefit to the deployment of microreactors.

3.7.1. Electrical Codes

The interview data indicated no major issues with codes and standards related to electrical design; however, one comment was made identifying the compact size of a microreactor may present a challenge to maintain the required separation of electrical circuits.

Gap 7.1 – Electrical system separation

Additional assessment of the potential challenges related to electrical circuit separation should be performed and determine if a gap exists where industry action can provide support in resolution of the gap.

3.7.2. Additive Manufacturing

ASME has developed standards that provide rules and guidance for applying additive manufacturing, but at least one designer mentioned that additive manufacturing still lacks clear C&S to follow.

Gap 7.2 – Application of additive manufacturing

Although this was only mentioned by one designer, there is potential application for a number of microreactor designers that choose to use additive manufacturing. The DOE Program on Advanced Manufacturing and Materials Testing has been performing several research and development tasks that can be reviewed to determine whether their activities can satisfy the statement of C&S still lacking for additive manufacturing.

4. GAP PRIORITIZATION

In this section, a prioritization matrix is developed for the gaps identified so far. First, a few criteria for prioritization are proposed, and these criteria are then applied subjectively to develop the prioritization matrix. This is a draft prioritization matrix and is not comprehensive or final. In the next phases of the project, further feedback from designers and C&S SMEs will be used to adjust the gaps, criteria, as well as the matrix to improve it. As designers and design teams make progress in their designs, more gaps may be identified. The prioritization criteria are as follows:

1. Applicability across microreactor designs: This criterion refers to the number of microreactor designs or technology types affected by the gap. Gaps that cut across multiple microreactor designs are rated higher than those specific to a single design concept. The following numbers are used while applying this criterion:
    a. *Number of microreactor designs a gap applies to*
    b. *Number of designers that identified this as a challenge through industry engagement*
2. Impact on deployment: The degree to which the gap, if unresolved, would block or delay licensing or deployment. Gaps that represent hard licensing barriers—where no compliant pathway currently exists—are rated higher than gaps that add cost or schedule risk but can be navigated through existing frameworks. This criterion is applied based on answers to the following questions:
    a. *What deployment phase does this relate to (e.g., pre-licensing, licensing and siting, construction and manufacturing, operations and transportation)? Earlier deployment phases generally imply higher criticality, as pre-licensing gaps must be resolved before any subsequent activity can proceed.*
    b. *Does the gap prevent deployment entirely, or does it require modifications to the current deployment plan or add cost/inefficiency only?*
    c. *Is this necessary for first-of-a-kind deployment?*
    d. *Is there a workaround for this gap that requires additional effort and C&S changes can make it easier?*

3. Need for DOE action: If a gap may be resolved through existing industry, regulatory, or SDO efforts in a timeframe consistent with microreactor deployment goals without DOE intervention, it is rated lower. This criterion is applied based on answers to the following questions:
   a. *Has the gap been identified in existing advanced reactor C&S assessments performed by other organizations such as the ARCSC and NEI? Note: A gap shared with advanced reactors in general (in addition to microreactors) is not automatically likely to self-resolve—overlap with existing assessments reduces urgency only if the gap is being actively addressed at a pace consistent with microreactor deployment.*
   b. *Is the gap being actively addressed by an SDO? If no, is the gap clearly associated with a specific SDO, or is there a lack of a clear "owner"?*
4. Value of DOE action: The degree to which DOE engagement would meaningfully accelerate resolution beyond what industry or SDOs could achieve independently. Gaps are ranked higher if DOE and national labs' involvement provide a unique advantage and ranked lower where industry or SDOs are well-positioned to resolve the gap without DOE involvement. This criterion is applied based on answers to the following questions:
   a. *What type of action is needed for resolution (e.g., R&D, multi-agency coordination, SDO engagement)?*
   b. *Does resolution require new experimental data (e.g., irradiation testing, materials characterization, thermal-hydraulic experiments)?*
   c. *Does resolution require validation or benchmarking of new computational tools or analysis methods?*
   d. *Can individual designers reasonably fund any required R&D, or does the scale and shared benefit of the work require a DOE national laboratory investment?*

The gaps identified in Section 3 are assessed on the prioritization criteria in Table 1. The gaps were subjectively rated across the four criteria, and a rating from 1 (high importance) to 5 (low importance) was calculated based on the average score across the four criteria. The lowest score therefore indicates the highest priority. These scores and the rating are subjective and will be updated as the project continues through the rest of the phases.

The final ratings show that the qualification of non-metallics[a] is of the highest priority, followed by ASME Section III, Division 5 Design by Analysis, inspections and condition monitoring, deployment of materials in high-temperature operating environments, lack of a type C container in the United States, lack of high-temperature material standard for packaging, and electrical separation. These are rated high priority because (a) they are critical for the deployment of a first-of-a-kind microreactor and (b) specific to microreactors so there is a low likelihood of parallel efforts addressing these gaps. As the project continues through the next phases, more information will be gathered on each of these gaps, including reaching back out to designers, reaching out to SMEs, and SDOs to reevaluate the scoring for each gap.

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[a] The non-metallics considered here are graphite and Beryllium Oxide. While graphite is being addressed in other DOE programs like Gas-Cooled Reactors (GCR), Beryllium Oxide is likely not, and given its importance for compact microreactors, it was rated high.

Table 1. Draft prioritization matrix for the C&S gaps identified in this report.

#	Title	Applicability across microreactor designs	Impact on deployment	Need for MRP action	Value of MRP action	Score	Rating
1.1	ASME Section III, Division 5 Design by Analysis	high	med	med	med	2.25	2
2.1	Inspections and condition monitoring	high	high	low	med	2.25	2
3.1	Deployment of materials in high-operating temperature environments	high	high	low	med	2.25	2
3.2	Qualification of non-metallics for use in microreactor operating environments	high	high	med	med	2.5	1
4.1	Lack of type C container standard in the United States	med	low	high	high	2.25	2
4.2	Lack of high-temperature material standard for packaging	high	low	high	med	2.25	2
4.3	Limited material coverage in ASME strain-based failure criteria	med	med	low	med	1.75	4
5.1	Use of commercial C&S	high	med	low	med	2	3
6.1	Lack of guidance on the use of digital twins	high	low	med	low	1.75	4
6.2	Lack of guidance on use of autonomous systems	high	low	med	low	1.75	4
7.1	Electrical system separation	med	high	med	med	2.25	2
7.2	Application of additive manufacturing	high	low	low	low	1.5	4

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