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Mid-year Progress Update on ORNL Support for Developing the Guidance for Microreactor Manufacturing Licenses

A. Huning
R. Belles
S. Arndt

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OAK RIDGE National Laboratory

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Nuclear Energy and Fuel Cycle Division

MID-YEAR PROGRESS UPDATE ON ORNL SUPPORT FOR DEVELOPING THE GUIDANCE FOR MICROREACTOR MANUFACTURING LICENSES

Alexander J. Huning
Randy J. Belles
Steven A. Arndt

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Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831
managed by
UT-BATTELLE LLC
for the
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ABSTRACT

Factory fueling and assembly, multi-site operation, and the associated transportation of advanced nuclear systems present both new opportunities and challenges for microreactor deployment. These areas have not been demonstrated under Nuclear Regulatory Commission rules and regulations. A goal of the Systems Integration and Analysis technical area under the US Department of Energy Microreactor Program for the current fiscal year is to articulate these challenges and provide industry recommendations. This mid-year progress report describes the progress and some of the contributions to this effort by the Advanced Reactor Engineering and Development section at Oak Ridge National Laboratory. The content provided here is preliminary and may change before being incorporated into a later report, which is expected to be completed in September 2022.

1. INTRODUCTION

At the start of the 2022 fiscal year (FY), the Systems Integration and Analysis (SIA) technical area under the DOE Microreactor Program (MRP) was tasked with investigating regulatory challenges associated with manufacturing licenses for microreactors. This scope was modified in early 2022 to also include transportation, as the Nuclear Energy Institute (NEI) and U.S. Nuclear Regulatory Commission (NRC) have made considerable progress toward outlining the potential options for Part 53 manufacturing licenses.[1]

Due to the modification of scope from the original activity, manufacturing license recommendations were provided in an interim report in February of 2022 [1]. Microreactor-related issues pertaining to transportation (Part 71) will be presented in September 2022.

This report documents progress in both the manufacturing license and transportation regulatory development by Oak Ridge National Laboratory (ORNL) as part of the joint ORNL and Idaho National Laboratory (INL) SIA technical area activity for FY22. The next section documents recent background on the subject.

2. BACKGROUND

In November 2019, the NEI published a white paper on microreactor regulatory issues [1], which was presented to the NRC at a public meeting. The white paper describes several policy and technical issues related to microreactors. Principally, these issues included NRC review scope, autonomous operation, NRC oversight and inspections, emergency preparedness, physical security, and aircraft impact assessment. Manufacturing and transportation were also identified but not explicitly described.

Following this, the NRC reviewed and provided feedback in SECY-20-0093 [2]. The topic of manufacturing licenses and transportation was addressed. It was noted that the staff had previously considered this issue for small modular reactors (SMRs) in the enclosure to SECY-10-0034 [3]. The main difference for microreactors now is that the entire plant could be manufactured and transported to the site and possibly between sites. Finally, it was noted that

[1] Part 53 has a potential to offer enhanced flexibility of requirements with the use of risk-informed tools. A summary of some microreactor considerations associated with the development of Part 53 has been performed by ORNL and is included as an appendix to have a concise document for reference into a final joint, INL and ORNL report.

> …guidance may need to be developed for implementing the requirements for manufacturing licenses, and potential policy issues may arise, for example, with regard to transportation of fueled reactors [3].

In July 2021, NEI published a paper on "Manufacturing License Considerations for Part 53" [4]. Potential business cases were described as part of the motivation for presenting the options for developing the manufacturing licenses requirements in Part 53. These options were presented as follows:

1. Part 53 Only Option
2. Part 53 Centric Option
3. Part 53 Limited Option

Each option contained a decreasing degree of reliance on new regulations for manufacturing licenses. Under the Part 53 Limited Option, only advanced reactor safety requirements would be established. All other regulations, such as those for factor fueling, would be addressed in existing regulations (i.e., Part 70–72). In the Part 53 Only Option, all requirements—such as those for factory fueling, transportation, decommissioning, and so on—would be rewritten in Part 53 and would presumably utilize risk-informed terminology and concepts similar to those described for advanced reactor safety requirements. In the Part 53 Centric Option, a blend of requirements relevant to the design and approval processes would be included, but pointers to other Part 70 requirements would still be used. NEI recommended a limited approach, as it provides "the clearest regulatory structure for accommodating the various in-factor activities" [4].

At roughly the same time, a limited-scope Regulatory Research Development Plan (RRDP) was developed as part of the MRP [5]. Interviews with microreactor developers were conducted to determine areas that need additional regulatory development. Factory assembly, manufacturing licenses, and transportation were considered high priority for microreactor developers but were not already being addressed through other programs. For example, modeling and simulation was identified as one of the highest priority topics but is being extensively investigated by the DOE NEAMS program [6], as well as other national laboratories and industry groups.

In September 2021, the NRC published a draft white paper on "Micro-reactor Licensing Strategies" [7]. On the topic of manufacturing licenses, the white paper states the following:

> The NRC staff members involved in the 10 CFR Part 53 rulemaking are exploring ways to increase flexibility for manufacturing and transporting a fueled reactor to an approved site under a manufacturing license. However, scenarios involving starting and testing a reactor in the factory under a manufacturing license are beyond the current scope of the 10 CFR Part 53 rulemaking because an OL or COL would be required for operation of a reactor at the manufacturing sites [7].

One key takeaway from the NRC paper and Part 53 development is that factory criticality and operational testing will not be possible with a manufacturing license. For this to occur, an operating license or combined operating licenses will be required at the factory facility. This is not a prohibitive roadblock, but it increases the complexity within the required safety analysis and environment reports. A summary of this and other microreactor considerations observed in the draft consolidated Part 53 can be found in Appendix A. Only limited additional guidance can be developed with respect to manufacturing licenses and Part 53 due to the draft and rapidly evolving development process involving the NRC and industry stakeholders.

3. PROGRESS AND SUMMARY OF ORNL CONTRIBUTIONS

Guidance for manufacturing licenses will depend on the development of Part 53. A new consolidated draft of Part 53 is expected later this year. The critical open issue is whether additional frameworks beyond framework A (the risk-informed approach) will be in a more complete state. Another open issue is which of the three options that NEI has identified will be incorporated in the new consolidated draft with respect to manufacturing licenses. NEI has recommended that a Part 53 Limited option be developed. No criticality testing or operational testing of the reactor could be performed at the facility unless an operating license is obtained. A Part 53 Centric or Only option may be more applicable for any vendor that seeks to pursue the testing route. Depending on the outcome of Part 53 development, more specific guidance may be developed.

Nuclear fuel facilities, like those that would load the fuel into a microreactor before shipping to an operating site, are also regulated under 10 CFR Part 70. These requirements would also need to be met in addition to the manufacturing license requirements—in particular, Subpart H, which defines requirements for the integrated safety analysis. The packaging and shipping of nuclear material is regulated by 10 CFR Part 71. Independent storage of nuclear fuel is regulated by 10 CFR Part 72. Requirements in all three of these areas may impact the licensing associated with transportation of fueled microreactors. Challenges related to transportation of microreactors include

- licensed shipping packages,
- accident and safety analysis,
- criticality safety and controls, and
- emergency planning.

These challenges may be distinctly different for fully fueled microreactors than for traditional light-water reactor fuel and spent fuel. In terms of progress on the development of guidance for transportation, this scope was added in early 2022 and information is being gathered while potential recommendations are being discussed.

Mid-year ORNL contributions on this task can be described in terms of three principal categories:

1. documentation,
2. meetings/presentations, and,
3. NRC and industry involvement.

In terms of published documentation, this report and appendix may provide some input into the final report expected in September 2022. Additionally, ORNL review and input were provided in the February 2022 update. Documentation has been informal, contained in meeting notes from both MRP and industry activities, presentations, and email discussions both internally and externally at ORNL. Additionally, review of NEI, NRC, INL, and ORNL reports associated with microreactor regulatory reports, Part 53 development, and transportation has been performed. These documents will continue to be generated and then consolidated in the September 2022 report.

In terms of NRC and industry involvement, the NRC holds periodic advanced reactor stakeholder meetings—although not specifically addressing microreactors—that ORNL has attended. During FY22, these meetings were held in November, January, and March. Part 53 development is routinely discussed at these meetings. ORNL will continue to attend and follow advanced reactor licensing development, as many topics are cross-cutting with microreactors. For example, physical security, emergency preparedness, siting, and so on are cross-cutting with micro- and large advanced reactors.

ORNL will continue to work with the task lead and support the development of guidance for manufacturing licenses and transportation of microreactors in the second half of FY22. Sufficient funding and resources exist for the development of a high-quality joint INL and ORNL report expected in September 2022. ORNL will continue to participate and capture NRC and industry developments that may impact future guidance. Additionally, future microreactor licensing challenges (e.g., vendor licensing developments) may be presented or promulgated that warrant a response from the MRP; these challenges may also require future research by DOE, which would offer significant benefit to the industry. ORNL will continue to be cognizant of such developments and provide ideas for future work to address emergent challenges related to microreactor licensing.

4. REFERENCES

[1] Christensen, A., *Manufacturing Licenses for Microreactors,* Idaho National Laboratory, INL/RPT-22-66051, Revision 0, (February 2022).

[2] Nuclear Energy Institute, *Micro-Reactor Regulatory Issues,* ADAMS Accession No. ML19319C497, (November 2019)

[3] Nuclear Regulatory Commission, *Policy and Licensing Considerations Related to Micro-Reactors,* SECY-20-0093, ADAMS Accession No. ML20254A363, (October 2020).

[4] Nuclear Regulatory Commission, *Enclosure – Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs,* SECY-10-0034, ADAMS Accession No. ML093290290, (April 2010).

[5] Nuclear Energy Institute, *Proposed Approach for Manufacturing License Requirements in 10 CFR Part 53,* ADAMS Accession No. ML21197A103, (July 2021).

[6] Christensen, J., W. Poore, and R. Belles, *Regulatory Research Planning for Microreactor Development,* Idaho National. Laboratory, INL/EXT-21-61847, Revision 1, (July 2021).

[7] Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program, Website: neams.inl.gov, Accessed: April 27, 2022 (April 2022).

[8] Nuclear Regulatory Commission, *Draft White Paper on Micro-Reactor Licensing Strategies*, ADAMS Accession No. ML21235A418, (September 2021).

APPENDIX A. Part 53 Considerations for Microreactors

In February 2022, the NRC published the consolidated Part 53 preliminary proposed rule language [A1]. The consolidated Part 53 preliminary proposed rule is a compilation of many subparts that are currently under development by the NRC and receive industry stakeholder feedback. Part 53 is expected to be an alternative licensing pathway for advanced reactors, including microreactor designs. Although traditional Part 50/52 licensing pathways will still be an option, the new Part 53 is intended to be more technology inclusive, risk-informed, and performance-based. The Part 53 development schedule is shown in Figure 1.

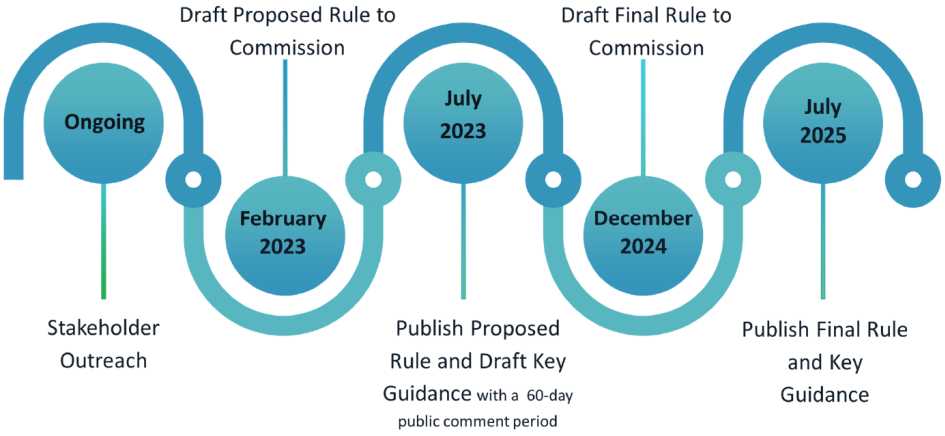

Figure A-1. Part 53 Rulemaking Schedule [A2]

Initial development of Part 53 formally began in late 2020 when the commission approved the staff's proposed approach for the development of Part 53 rulemaking activities [A3]. As shown in Figure A-1, Part 53 rulemaking is currently in the stakeholder outreach phase. A new preliminary proposed rule is expected to be published in May 2022. Formal comments on this preliminary proposed rule are due on August 31, 2022 [A4]. After that date, the NRC will disposition each and develop a draft proposed rule with an additional public comment period and commission review. As such, the insights and conclusions drawn from this preliminary proposed rule are also preliminary and may be inconsistent or not applicable when the draft rule is proposed to the commission. However, it is important to stay abreast of the implications for microreactors: there is still opportunity to recommend changes to the preliminary proposed rule language. The high-level contents of Part 53 are outlined in Table A-1.

Table A-1. Preliminary Proposed Part 53 Subpart Contents

Subpart A	General provisions
Subpart B	Technology inclusive safety requirements
Subpart C	Design and analysis requirements
Subpart D	Siting
Subpart E	Construction and manufacturing
Subpart F	Operations
Subpart G	Decommissioning
Subpart H	Licenses, certifications, and approvals
Subpart I	Maintaining and revising licensing basis
Subpart J	Administrative requirements
Subpart K	Quality assurance

From 2020 to the time of this writing, several changes to the subparts and the overall structure of Part 53 were implemented. Pursuant to industry feedback, an alternative framework to the PRA-reliant framework developed initially is also being proposed as an option. In the consolidated preliminary proposed rule from February 2022, this alternative framework is labeled as "Part 5X Supplement – Technology-Inclusive Alternative Requirements for Commercial Nuclear Power Plants." However, in an NRC presentation on March 16, 2022, these two distinct frameworks are presented closer to equal ground (i.e., alternative framework requirements will not reference or child from primary framework requirements). Framework A (Figure 2) contains the subpart language referencing the enhanced use of PRA, and Framework B (Figure 2) contains the more traditional requirements that may or may not use a PRA and was developed in response to industry and stakeholder feedback to the initially proposed Framework A language. High-level differences between the two frameworks are illustrated in Figure A-2.

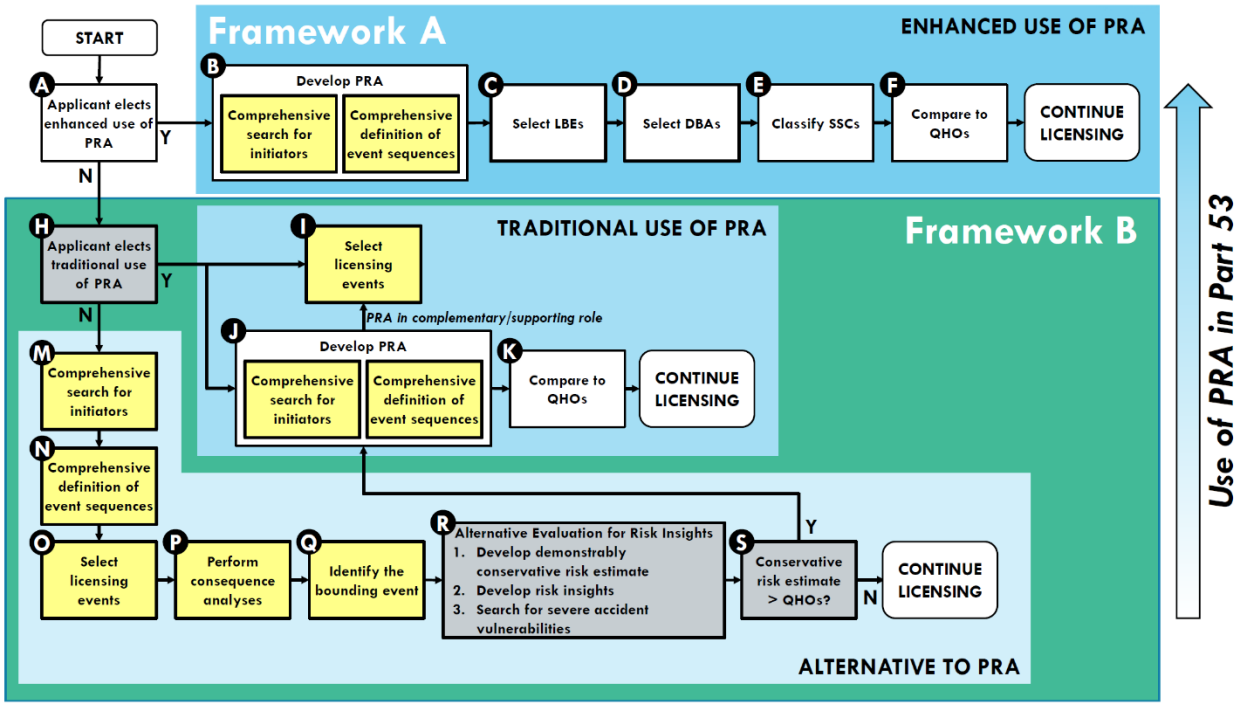

Figure A-2. Part 53 Framework Options [A2].

Except for Subpart C, design requirements, both frameworks will be contained in the subparts listed in Table 1. Design requirements for Framework B are expected to be like existing requirements related to general design criteria or advanced reactor design criteria in support of developing plant-specific principal design criteria. Design requirements for Framework A include the requirement for a PRA, risk-informed SSC classifications, event sequences, and areas that are not applicable for Framework B. The requirements within each subpart are expected to be different for each framework due to the inclusion or exclusion of the enhanced use of PRA. Observations relevant for microreactors from both frameworks are discussed below.

A.1 Framework A observations

The critical difference between Framework A and B is the requirement and use of PRA in the language of the subpart requirements. If the developer elects not to pursue a PRA or have a limited PRA application, then Framework B will be selected if a Part 53 licensing approach is used. There are many factors that may influence the decision to develop a PRA for a microreactor. For Framework A, relevant to microreactors, observations of the preliminary proposed rule language include the following:

- a strong motivation exists for prelicensing engagement and design-specific agreement with the NRC on risk-informed terminology and parameters (e.g., what is risk significant, risk margin, etc.)
- most of the high-level application content is not new with some programs, just rephrased (e.g., integrity assessment program)
- potential challenges may exist in the analysis of licensing basis events (LBEs) and non-design basis accidents (DBAs)
- inclusion of manufacturing licenses and capability for factory fueling is beneficial
- transportation and fuel cycle activities are largely unchanged
- risk-informed flexibility is offered throughout the subparts for operations, staffing, security, and other areas
- potentially lower quality assurance requirements for most systems and components that are not safety related or not safety related but safety significant
- Quantitative Health Objective (QHO)-based safety criteria may be challenging for very unlikely events (also called beyond design basis events)
- a strong motivation exists for lowering the predicted consequences of DBAs, as well as all unlikely and very unlikely events

In terms of safety analysis requirements for manufacturing license applications, some key information to consider:

- multi-module and facility hazard effects must be analyzed in the safety analysis,
- criticality tests cannot be performed at the facility, and criticality prevention must be shown
- safety and security analyses must include accidental criticality
- many of the same requirements required for fuel cycle facility (e.g., emergency plans, fire protection, plant staff training program)

Currently, criticality and low-power testing is not allowed in the Part 53 preliminary proposed rule. Performing these tests at the factory may potentially be more efficient or offer some other benefit. Additionally, some microreactors are being designed for mobile operation at different sites. One solution would be to license the factory as one of these sites. Evaluating the tradeoffs may demonstrate cost savings in the long run. However, navigating this business unit complexity would be a significant challenge since in the US, fuel and manufacturing companies are not the same as the nuclear generators and operators.

A.2 Framework B (Part 5X Supplement) observations

This alternative to Framework A, which assumes an enhanced use of PRA, is more deterministically based and intends to achieve the same level of safety. The bulk of the modifications are contained within Subpart B, technology-inclusive safety requirements. It is assumed that the other subparts would be very similar to Framework A, although the complete list of potential changes was not included in the February 2022 consolidated Part 53 proposed rule language. For Framework B, relevant to microreactors, observations of the preliminary proposed rule language include the following:

- the term “risk assessment” is commonly replaced where the term “probabilistic risk assessment” is used in Framework A
- the risk assessment can include either a PRA or another systematic approach for evaluating engineering systems
- principal design criteria must be specified using the General Design Criteria (GDCs) or other generally accepted consensus codes and standards
- bounding safety analyses must be performed for the full range of AOOs and DBAs with sufficient margin

- bounding analyses are not required to be realistic to provide reasonable assurance that operation of the facility could not exceed the dose safety requirements (i.e., maximum credible or hypothetical accident approaches)
- no requirement for QHO evaluation is present; however, this could be added later as this is still being developed
- the same Part 100 and DBA dose criteria in Part 50/52 are specified
- functional containment is offered as an alternative to traditional containment requirements,
- single failure criterion is included and would also encompass passive components which are safety related, and
- additional design features or programmatic controls should be developed to establish supplementary protections to mitigate against recognized beyond-design-basis event initiators

A.3 Summary of Part 53 microreactor considerations

For proponents of the PRA approach, Framework B includes many items that were removed in Framework A for which the PRA and risk results could eliminate the need. These principally include items such as

- principal design criteria derived from GDCs and/or Advanced Reactor Design Criteria (ARDCs),
- the single failure criterion,
- bounding safety analyses that may conflate accident consequences leading to over-conservatism in the design, and
- the requirement for additional beyond design basis event (BDBE) controls for events that may have a sufficiently low frequency and consequence that risk-informed safety criteria and QHOs could be satisfied.

For proponents of Framework B, these items are not believed to be of a substantial cost to the design of the plant, and it eliminates the need for the perceived high cost associated with developing the PRA and validating complex underlying data and assumptions.

As it relates to microreactors, it is the authors' view that either framework could be successfully implemented. The simplicity in design leads toward a potentially simpler PRA with fewer events. A simpler design would also make bounding calculations easier. However, there are some unique challenges for microreactors that follow either framework would face.

- PRA or bounding calculations involving transportation modes, secondary sites, and other sites will be more challenging where seismic and external hazards could be quite distinct
- enveloping seismic and external hazards is nontrivial for PRA approaches because frequent, less severe events could contribute more toward cumulative risk metrics than infrequent severe events
- smaller exclusion area and emergency planning radii leading to potentially higher doses
- smaller changes in weather, dispersion, and transient release assumptions could have a much larger impact on the ability to meet dose criteria at these exclusion area and emergency planning distances for either bounding calculation or probabilistically determined licensing basis events
- with minimal staff, human actions may have a larger importance on mitigation, even if they are not required to meet the safety criteria
- the single failure criterion may be more of a challenge to meet under Framework B because it is unlikely that a significant number of redundant safety systems would be employed in these smaller systems

No recommendation is made in this report for microreactors to follow either Part 53 Framework A or Framework B or another alternative approach. This decision requires careful consideration of several factors, including the (a) development and deployment schedule, (b) technology selections, (c) fuel type

and fission product release data, and fuel qualification, (d) operational characteristics (e.g., transportability/mobility, refueling scheme), and (e) availability of test and/or demonstration unit data. However, any reactor with a deployment schedule on or before the year 2027 would likely not follow a Part 53 approach, as this is when the new regulations, and any resulting regulatory guides, are expected to take effect.

A.4 References

[A1] U.S. Nuclear Regulatory Commission, *Consolidated Part 53 Proposed Rule Language*, ADAMS Accession No. ML22024A066, (February 2022).

[A2] U.S. Nuclear Regulatory Commission, *Advanced Reactor Public Stakeholder Meeting, March 16, 2022,* ADAMS Accession No. ML22038A001, (March 2022).

[A3] U.S. Nuclear Regulatory Commission, *Staff Requirements – SECY-20-0032 – Rulemaking Plan on Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors,* SRM-SECY-20-0032, ADAMS Accession No. ML20276A293, (October 2020).

[A4] Federal Register, Proposed Rules, "U.S. Nuclear Regulatory Commission, 10 CFR Part 53," 82 FR 235, (December 2021).