NEI White Paper

Micro-Reactor Regulatory Issues

Prepared by the Nuclear Energy Institute
November 13, 2019

Acknowledgements

This document was developed by the Nuclear Energy Institute (NEI). NEI acknowledges and appreciates the contributions of the NEI Micro Reactor Task Force, NEI members and other organizations in providing input, reviewing and commenting on the document.

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Executive Summary

Micro-reactors are very small nuclear reactors that are well suited to serve the power needs for markets that currently do not have access to clean, reliable, resilient and affordable energy, including remote areas and micro-grids.

Micro-reactor technology and designs are rapidly maturing and the first micro-reactor applications are expected to be submitted to the U.S. Nuclear Regulatory Commission (NRC) in 2020. The purpose of this report is to discuss changes in the way micro-reactors are licensed and regulated. This also identifies the need to address several policy and technical issues. Timely NRC consideration and feedback on the policy and technical issues associated with a performance-based, consequence-oriented regulatory framework is needed to inform design of micro reactors as well as business decisions affecting licensing and certification of micro-reactors over the next few years.

> *"The characteristics and safety profile of micro-reactors are fundamentally different from those of larger nuclear reactors for which the existing regulations were developed."*

Micro-reactors will have very small radionuclide inventories as compared to large light-water reactors, and some may assure safety entirely through inherent and passive design features. These features are expected to result in micro-reactors that have very low potential for consequences that could impact public health and safety. As a result, the NRC should consider alternative approaches for micro-reactors that can demonstrate that the potential consequences of accidents, even for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public. Micro-reactor designs that can meet these conditions may be able to justify the use of alternative approaches to meet the regulations and protect the public health and safety. Included in this report are identified actions that are likely needed to help develop the information needed to help inform the NRC's consideration of alternative approaches.

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1 INTRODUCTION

Micro-reactor technology and designs are rapidly maturing and the first micro-reactor applications are expected to be submitted to the U.S. Nuclear Regulatory Commission (NRC) in 2020. The purpose of this report is to discuss policy and technical issues associated with the regulation of micro-reactors that have not been addressed to-date. The Nuclear Energy Institute anticipates the need to and benefits of working with the NRC staff to address these issues and develop a more performance-based consequence-oriented regulatory framework appropriate for micro-reactors.

The NRC has two licensing pathways for power reactors described in 10 CFR Part 50 and 10 CFR Part 52. In the Part 50 licensing pathway, the NRC will initially approve a construction permit that only allows for construction of the nuclear power plant, and is later followed by NRC approval of an operating license. In the Part 52 licensing pathway, the NRC will approve a combined construction and operating license (COL). The COL may, but does not have to, reference a design certification (DCD). The DCD allows for NRC pre-approval of the design of a nuclear power plant without a specific site. The COL may also, but does not have to, reference an early site permit (ESP). The ESP allows for NRC pre-approval of certain aspects of a site, including the environmental review. After construction is completed, the NRC must verify the completion of the Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) before the reactor can begin operations. These licensing pathways are discussed in more detail in the NRC's FAQ about license applications for new reactors.[1]

Regardless of which licensing pathway an applicant chooses, a performance-based, consequence-oriented regulatory framework is needed for micro-reactors, because the existing regulatory framework for power reactors does not appropriately consider the extremely low potential consequences of accidents that are expected for these designs. Establishing such a framework will help to avoid imposing undue regulatory burden on micro-reactors, and incentivize designers to incorporate features that reduce the risk of accidents.

In the near-term micro-reactor applications are expected to use alternative approaches and exemptions to the existing regulations. In the future, rulemaking, either to holistically address micro-reactors (for example, in the NRC's consideration of Part 53) or for a specific topical area (such as physical security) is likely needed in order to establish an appropriate framework for micro-reactors. As such, it is important for the NRC to engage in discussion with applicants and stakeholders to determine an approach for exemptions to certain requirements, or demonstrating how these requirements are met through alternative means. These approaches could be established through NRC policy decisions, guidance or through proposals by the applicant. Timely NRC consideration and feedback on the acceptability of the policy and technical issues associated with a performance-based, consequence-oriented regulatory framework for micro-reactors is needed to inform design and business decisions affecting licensing and certification of micro-reactors over the next few years. As discussed below, consideration of such an approach would be consistent with the NRC's Advanced Reactor Policy Statement. It is noted that, micro-reactor applicants will need to demonstrate and the NRC will need to independently verify that the design achieves a level of safety that would enable the use of these alternative approaches.

[1] https://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0468/index.html

1.1 Micro-Reactor Description

Micro-reactors are an emerging nuclear energy technology that are intended to address energy needs in a number of markets. Customer interest in this innovative technology is growing rapidly. Micro-reactors are very small nuclear reactors, typically in the 2 MW-thermal to 40 MW-thermal range with some designs being even larger or slightly smaller. This power output is 100 to 1,000 times smaller than a typical large light water reactor. Micro-reactors could be small enough to fit on the back of a tractor trailer, which includes not just the reactor itself, but also the power conversion system. When placed in the operating location, micro-reactors can be housed inside buildings with footprints as small as 1,000 square feet.

The operations and maintenance of micro-reactors are expected to be highly simplified through the use of automatic and/or remote operations/monitoring, the minimization of structures, systems and components (SSCs), and the maximization of the reliance on inherent and passive safety features. It is possible that a micro-reactor could justify having only a single individual on-site per shift, and a total plant complement with as few as five full-time equivalents (FTE), if the single individual on-site would be sufficient to perform all of the necessary actions to keep the plant operating safely and securely, such as monitoring the operations of the reactor, maintenance, radiation protection, security and emergency response.

1.2 Uses and Applications

Micro-reactors are well suited to serve the power needs for several markets that currently do not have access to clean, reliable, resilient and affordable energy. Many of these markets are in remote areas, such as arctic communities, island communities, and mining operations. However, micro-reactors are also an option to power secure micro-grids for critical infrastructure such as defense installations and emergency response facilities, some of which may be in densely populated areas.

Micro-reactors are being designed to protect against severe natural phenomena as well as man-made physical and cyber security threats, and many are being designed with the ability to operate in island-mode and to have black-start capabilities, which means they can initiate recovery from a loss of power to the site. Thus, micro-reactors are an ideal generation source for uses that need to operate independently from the electric grid to supply highly resilient power for critical loads under normal and emergency conditions.

Micro-reactors can produce power on-demand and operate independent of weather conditions. Micro-reactors can include the ability to vary their power output to match changes in demand. This attribute makes micro-reactors suitable to serve changing loads and compatible with intermittent sources of energy like renewables.

Micro-reactors that offer high reactor outlet temperatures can produce both electricity and heat, or can be used exclusively to provide one or the other. The electricity or high-temperature heat from a micro-reactor can also be used to desalinate and purify water, and to generate hydrogen. Heat can be used for industrial applications such as oil refining and chemical processing, and in colder climates, can be used for district heating of homes and businesses. The use of micro-reactors to produce heat for industrial processes or district heating can improve the utilization of the micro-reactor in areas with variable demand for electricity, thus increasing the market demand for micro-reactors.

2 KEY REGULATORY POLICY AND TECHNICAL ISSUES

The characteristics and safety basis of micro-reactors are expected to be fundamentally different from those of larger commercial power reactors. The NRC should consider alternative approaches for micro-reactors that can demonstrate that the potential consequences of accidents, even for the worst-case scenarios in which there are multiple failures of fuel fission product barriers and other systems, structures and components, would not lead to a significant adverse impact on the health or safety of the public.

The key feature of micro-reactors is their very small inventory of fission products, as compared to currently licensed power reactors. Micro-reactors are expected to come in a variety of designs and while there is not a standard set of micro-reactor features, the following are some of the more common safety enhancements that are expected to be incorporated into the designs (note not all of these features are applicable to all designs):

- Safety provided entirely by passive and inherent features (e.g., long term passive cooling with natural forces to sufficiently transfer decay heat indefinitely with the loss of any fuel fission product barriers)
- Fail-safe to shut down automatically
- Accident and proliferation resistant fuel with enrichments below 20% U-235
- High fission production retention
- Operator actions are not needed to assure safety of the reactor
- Reactor can be constructed completely below ground
- Operational simplicity with very few instruments and controls, and active SSCs

2.1 Framing the Regulation of Micro-Reactors

For micro-reactors that can meet the above safety case, the existing regulations and proposed rule changes to address advanced reactors, in many cases, would result in excessive regulatory burden that is not necessary to protect the public health and safety. The safety features, and the corresponding simplicity of micro-reactors, are expected to result in designs with very low potential consequences, which could justify the use of alternative approaches to existing regulations.

The NRC does have experience regulating reactors with potential consequences similar to those expected for micro-reactors, specifically the regulation of non-power reactors under 10 CFR 50, which are classified as research and test reactors under 10 CFR Part 50.21(c) or 50.22. While micro-reactors are similar to research and test reactors (RTRs) in terms of their power level and potential consequences, there are also notable differences that would make it difficult to regulate micro-reactors under the research and test reactor paradigm. However, insights from the underlying safety bases of RTR regulations could be useful in considering alternative approaches for micro-reactors.[2] For example, many of the underlying bases for RTR requirements are based upon the very low potential consequences to the public. It is noted that some approaches taken by RTRs may not be appropriate for micro-reactors, for example comparing dose consequences to the 10 CFR Part 20 criteria.

In considering insights from the regulation of RTRs, it is important to make allowances for the differences between RTRs and micro-reactors, in particular:

- Micro-reactors are expected to operate at full power more frequently and for longer periods and have a balance of plant;

- Micro-reactors are expected to inherent safety features such that some accident scenarios may not be relevant (e.g., loss of coolant, loss of electrical power);

- Micro-reactors are expected to have automatic features that may not require human actions for accident response; and

- Micro-reactors are expected to be closed systems that do not perform tests and experiments, while RTRs range from open pool to pressurized light-water systems with power ranges of less than 1 MWt to 20 MWt. RTRs also have varying duty cycles from infrequent to nearly continuous operation and also typically perform tests and experiments (i.e., frequently perform non-routine operations).

The NRC's Principles of Good Regulation for Efficiency states "where several effective alternatives are available, the option which minimizes the use of resources should be adopted." In the application of this principle to micro-reactors, the safety requirements for micro-reactors should be focused on ensuring that micro-reactors meet the underlying intent of the regulations to provide reasonable assurance of adequate protection of the public health and safety. As a result, micro-reactors would likely not need to meet all of the existing detailed and prescriptive requirements that were developed based on the potential consequences of larger power reactors to ensure public health and safety.

The regulatory approach for micro-reactors should be flexible and accommodate multiple approaches that may be taken by applicants to demonstrate the safety basis. The regulatory framework for micro-reactors should be performance-based consequence-oriented. A graded approach to applying requirements is appropriate, since there is expected to be variation in the safety characteristics even among micro-reactors. While more information about the range of micro-reactor designs is needed to fully inform a potential rulemaking for micro-reactors, it is feasible to establish generic acceptance criteria that would enable micro-reactors to pursue alternative approaches to certain requirements – many of which are identified in this paper. It is advised that performance criteria for micro-reactors be based on the potential consequences rather than a prescriptive deterministic approach.

2.2 Key Policy and Technical Issues

As the development of micro-reactor designs continues to progress rapidly, the industry has discussed a number of potential policy and technical issues for micro-reactors. The appendices of this report discuss

[2] NUREG-1537, currently applicable to non-power reactors and isotope systems with a wide variety of technologies and safety basis, provides important insights and could serve as a more appropriate starting point than NUREG-0800 and Regulatory Guide 1.206.[2]

the following issues that we believe are unique to micro-reactors and are a high priority for early resolution (i.e., they are needed to be clarified for the first applicants):

1. NRC Review Scope and Level of Effort (Appendix A)
2. Operator requirements for automatic and remote operation/monitoring (Appendix B)
3. NRC Oversight and Inspections (Appendix C)
4. Emergency Preparedness (Appendix D)
5. Physical Security (Appendix E)
6. Aircraft Impact Assessment (Appendix F)

In addition, there are a number of important regulatory issues that micro-reactors have in common with other advanced reactors. However, these issues are not discussed in this report since they are being addressed through broader advanced reactor activities. The following is a representative (i.e., not exhaustive) list of other key regulatory policy and technical issues for micro-reactors that are common with other advanced reactor technologies:

1. Siting
2. Environmental Reviews
3. Fuel Qualification

2.3 Other Potential Micro-Reactor Issues

Other micro-reactor issues have been discussed, but either do not need to be clarified for the first applicants, or no significant issue has been identified to-date. Areas where it may be necessary for additional regulatory changes for micro-reactors in the future include:

1. Quality Assurance
2. Probabilistic Risk Assessment
3. Annual Licensee Fees
4. Liability Insurance
5. Decommissioning Funding
6. Transportation
7. Generic License

APPENDIX A: NRC REVIEW SCOPE AND LEVEL OF EFFORT

The NRC's existing regulations could be used for review of an application for a micro-reactor However, existing NRC requirements were developed decades ago based upon large LWR designs in operation today. The 2018 NEI white paper *Ensuring the Future of U.S. Nuclear Energy: Creating a Streamlined and Predictable Licensing Pathway to Deployment*[3] outlines the benefits of near-term regulatory changes to make the NRC licensing more streamlined and efficient. Better alignment of the NRC regulatory framework with the inherent enhanced safety and simplified designs of micro-reactors is particularly important to make the licensing process more efficient and predictable. The NRC continues to make progress on enhancing its ability to efficiently review advanced reactor license applications.[4]

The schedule and cost of the NRC review is directly related to the level of effort needed for the NRC to reach a safety finding. The level of effort in turn is driven by the scope of the review, which is related to the complexity and margin to safety of the design. Micro-reactors are expected to achieve high levels of simplicity and safety that would support a more streamlined NRC review. Ensuring that NRC reviews are efficient is one of the NRC's Principles of Good Regulation, which focuses on ensuring regulatory activities are consistent with the degree of risk reduction they achieve, adopting options that minimize the use of resources and making decision without undue delay. The pursuit of regulatory efficiency is important because the cost of licensing and oversight is likely to create an undue burden for micro-reactors, especially in consideration of the considerably reduced risks to the public health and safety that these designs are expected to achieve.

A.1 Current NRC Review Schedule and Cost

For Part 50, the NRC recently issued a construction permit for the SHINE radioisotope production facility in 36 months, measured from application tender to a decision on the construction permit. The NRC's target review schedule for a Part 52 COL that references a certified design is 30 months from docketing to approval.[5] A Part 52 COL application does not need to reference a design certification, and can describe a design that has not previously been approved by the NRC. The NRC has not established a target review schedule for a COL that does not reference a certified design. The NRC target schedule for a design certification review is 42 months followed by the design certification rulemaking. In addition to the licensing review schedule, the NRC also performs a review to determine if the application can be accepted, which typically takes 60 days. [6]

Recent history with issuance of design certifications (DCs) and combined licenses (COLs) for large light water reactors (LWRs) demonstrates that the licensing process is lengthy and expensive, even if the COL application references a DC for the reactor. The COL process has been around four years and $30M.[7] The experience with DC applications for LWRs has been similar. The costs of the NRC review of DC

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[3] https://www.nrc.gov/docs/ML1803/ML18030A771.pdf
[4] https://www.nrc.gov/reactors/new-reactors/advanced.html#visStrat
[5] NRC's NRO-REG-100; https://www.nrc.gov/docs/ML1407/ML14078A152.pdf
[6] Memorandum to the Commissioners dated March from Jennifer Uhle, entitled *Response to Staff Requirements Memorandum M140910 – Staff Report: 10 CFR Part 52 Application Reviews - Efficiency Opportunities and Review Timelines* (March 18, 2016), pp. 3-4.
[7] NRC Responses to Requests for Information from Senators James Inhofe and Shelley Moore Capito Letter Dated March 24, 2015, pp. 32-33.

applications have ranged from four to ten years, and between $45 million to more than $90 million in current dollars.[8]

A.2 NRC Review Targets for Micro-Reactors

The NRC should be able to conduct a more focused review of an application for micro-reactor designs that can demonstrate that the potential consequences of accidents, even for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public. For micro-reactors that meet these conditions, it is expected that applications would not need to include many of the accident scenarios (e.g., loss of coolant, loss of offsite power). Also, many of the safety systems (e.g., emergency core cooling, emergency diesel generators) that are common in previous generations reactor designs will not be necessary. Coupled with the expected size and simplicity of micro-reactors, applications may only include a small fraction of SSCs and initiating events, as compared to previous applications. While the development of a licensing approach for micro-reactors is beyond the scope of this paper, it is noted that developers have several options for developing applications that focus on the fundamental safety of the design.

The NRC should establish targets for its reviews that are reasonable based upon the level of safety, simplicity and size of the reactors. As evidenced by other NRC reviews, schedule targets have been important to ensure a timely review, whereas a lack of targets for level of effort have contributed to review costs that are unreasonably high. Micro-reactor applications are expected to be a fraction of the size of applications that were submitted for large LWRs. Micro-reactor designs are also expected to need a small fraction of the level of effort in design and engineering to achieve the maturity necessary for NRC licensing, as compared to large LWRs.

The NRC has been able to use limited scope reviews to license non-power production and utilization facilities, that have fission product inventories and potential consequences that are expected to be comparable with micro-reactors. On two recent NRC reviews of Part 50 construction permits (CPs), the NRC spent 22,000 hours for staff and contractor time on the SHINE facility, and 12,000 hours for staff and contractor time, for Northwest Medical Research.[9] At $275 per hour as specified in 10 CFR § 170.20, the cost of the review of the applications was approximately $6 million and $3 million respectively.

Given that it is expected that there will be significantly less information that the NRC needs to review, the schedule and level of effort of that review can be significantly less that it has been for previously licensed power reactors. Based upon NRC experience with RTRs, it is anticipated that a robust NRC safety and environmental review of a micro-reactor application could be performed with only a small fraction of the level of effort that has been expended on previous reviews. As discussed further below, there are also opportunities for the NRC to streamline their review and licensing processes to reduce and eliminate administrative burden that is expected to be unnecessary for the review of micro-reactors that meet the above conditions. For designs that achieve the above conditions, and assuming the NRC is able to streamline their review process, it may be possible for the NRC review of a Part 52 application (combined operating license or design certification) or a Part 50 application (construction permit or

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[8] Nuclear Energy Institute, *Recommendations for Enhancing the Safety Focus of New Reactor Regulatory Reviews* (April 2018), p. 8.

[9] SHINE Medical Technologies, Inc. (Medical Radioisotope Production Facility), CLI-16-04, 83 NRC 58, 61 (2016); Northwest Medical Isotopes, LLC (Medical Radioisotope Production Facility), CLI-18-06, 87 NRC 130, 133 (2018).

operating license) to be completed in less than 12 months from the acceptance of the application to the issuance of a Final Safety Evaluation Report.

The schedule and cost are equally important metrics for the review, and it is critical that the NRC's estimates for a specific application have reasonable certainty. In addition to establishing NRC review targets for micro-reactors, the NRC should establish more reasonable acceptance review targets for micro-reactors. Given that micro-reactor applications will contain significantly less information, the NRC should be able to complete the acceptance review for micro reactors within 30 days.

To help inform the NRC's consideration of targets for micro-reactor review schedule and level of effort, more detailed information should be developed on micro-reactor designs, including the types and number of SSCs, classification and safety significance of these SSCs, and the scope of the safety analyses for these designs. A standard template for a micro-reactor application, which could include a technical proposal on how the NRC can construct an appropriate scope of a safety-focused review for micro-reactors, would also help to streamline the NRC review.

A.3 Proposed Changes to NRC's Review Process for Micro-Reactors

There are a number of changes that could be made to the licensing process to reduce the duration and level of effort of licensing and certification of micro reactors that meet the previously stated conditions.[10]

1. The NRC draft *Non-Light Water Review Strategy* issued in September 2019 acknowledges that many requirements will not be applicable to micro-reactors, because micro-reactors either do not include the referenced system or cannot result in the postulated accident. The NRC should expect that much of its review guidance may not be applicable, and applicants may propose alternative approaches to demonstrating safety and compliance from the regulations. The NRC should expect that the content of the applications will also reflect the level of safety of the design. Similarly, the level of detail in the application will be less in areas where there is little to no safety significance. The NRC should establish a policy and process for ensuring that the level of effort allotted for review of the application are budgeted proportionate to the importance to safety and level of risk.

2. The Safety Evaluation Reports (SERs) for new reactors have typically been several thousand pages in length. In part, this is attributable to the format of the SERs. For example, the SERs contain redundant information (e.g., the Regulatory Basis sections and Technical Evaluation sections often include redundant descriptions of NRC regulations and guidance). Additionally, many SERs describe the request for additional information (RAIs) and the responses to the RAIs, rather than simply discussing the final design as reflected in the RAI responses. Similarly, the final SERs typically discuss each open item and unresolved issue and their resolution, rather than simply discussing the final design which includes the resolution of the open items and unresolved issues. The SERs should be streamlined to eliminate redundancy and discussions of the process of reviewing the design (rather than final design itself). By doing so, the NRC will

[10] In addition to the actions listed in the body of this report, the Nuclear Energy Institute (NEI) has identified a number of actions to improve the licensing process in general, such as relying upon well-planned audits, reducing the number of requests for additional information (RAIs), and reducing the level of detail in applications. *See, e.g., Recommendations for Enhancing the Safety Focus of New Reactor Regulatory Reviews* (April 2018).

shorten the length of the SERs, thereby reducing the duration and costs of its safety reviews (plus resulting in more readable SERs).[11]

3. It is noted that the number of phases and the processes of handing off work from one group (inside NRC or between NRC and a contractor) or individual to another adds inefficiencies and time. The NRC should consider reducing the number of phases needed to review smaller and simpler designs. As an example, there is no need for the Advisory Committee on Reactor Safeguards (ACRS) to review the application twice after different review stages, and the NRC should skip the step of issuing a draft SER with open items. The NRC should also look at consolidating work to fewer individuals and groups, and accelerating the time it takes to go through multiple levels of review by management and the Office of General Counsel.

4. The topic of NRC's review scope and level of effort is primarily focused on the safety review; however, it is recognized that the NRC should make improvements to other aspects of the review to improve the efficiency of its review of micro-reactors.

    a. The topic of environmental reviews is being addressed separately, as it is common to all advanced reactors, and will identify all areas where efficiencies in the environmental review could be achieved.

    b. The NRC should amend its regulations to require the use of a legislative hearing process, rather than the adjudicatory hearing process in Subpart C, for issuance of a license for a micro reactor. Under the legislative hearing process, issues would be resolved through submission of papers by the parties, without the need for an oral hearing or discovery. This would greatly reduce the duration and cost of the hearing process, and shorten the overall licensing duration, while maintaining opportunities for public participation.

    c. Congress should amend the Atomic Energy Act (AEA) to eliminate the AEA Section 185.b. requirement for a mandatory (uncontested) hearing for a license application for a micro reactor, while retaining statutory language that provides an opportunity for a contested hearing if interveners with legal standing raise admissible contentions. This change would eliminate the costs associated with the mandatory hearing. It would also reduce the duration of the licensing reviews, since the mandatory hearings are on the critical path to issuance of a license.

    d. The NRC should revise its regulations to provide for finality (absent significant new information) to issues resolved in previous licensing proceedings. For example, to the extent that a license applicant decides to co-locate a micro reactor at an existing reactor site, applicable environmental and siting issues (and some safety issues, such as emergency preparedness) for the existing reactor should have finality in the licensing proceeding for the micro reactor.[12] Additionally, the NRC should amend its regulations to preclude the need for a review of alternative sites for micro reactors co-located at existing reactor sites.

[11] The NRC can track the status of RAIs, open items, and unresolved issued issues in separate, less formal, data bases.
[12] NEI submitted a petition for rulemaking on July 18, 2001, to accomplish this result. The NRC denied this petition. 68 Fed. Reg. 57383 (Oct. 3, 2003).

APPENDIX B: OPERATOR REQUIREMENTS FOR AUTOMATIC AND REMOTE OPERATIONS/MONITORING

Micro-reactors are expected to be simple to operate, driven partially by the significant reduction in number of systems and components, and decreased reliance on human actions to ensure safety. Many micro-reactors are also expected to include automatic and/or remote operations/monitoring features. Some may be fully automatic and not require any operators, other than to initially commission the reactor and go critical, or to load and unload the fuel. The industry intends to work with the NRC to develop alternative approaches to licensed operators for micro-reactors that demonstrate they do not require continuous monitoring by an operator or any safety actions by an operator. Similarly, the industry intends to work with the NRC to develop alternative approaches to traditional control rooms for micro-reactors that demonstrate they only need a few instruments and controls at the reactor or at a remote center that provides operational control of a fleet of micro-reactors.

Micro-reactor designs will need to ensure that the control and staffing are adequate to protect the public health and safety. The subject of this paper is not to address the requirements for automatic and remote operations/monitoring of micro-reactors, but rather to discuss how requirements for operating staffing should be considered for a micro-reactor with automatic and/or remote operations/monitoring.

B.1 Existing Regulatory Requirements

The Atomic Energy Act (Sections 11 and 107) discusses operators for nuclear power plants, and grants the NRC discretion in the need and conditions under which operators may be licensed.[13] The regulations of the Nuclear Regulatory Commission (NRC) in 10 CFR § 50.54 contain license conditions applicable to "every nuclear power reactor operating license."[14] In particular § 50.54(i) through (m) contain requirements related to reactor operators (ROs) and senior reactor operators (SROs). Those regulations:

- require the licensing of ROs and SROs,
- allow for the manipulation of reactor controls only by ROs or SROs,
- require a RO or SRO to be present at the reactor controls at all times,
- state that an SRO shall be present at the facility or readily available on call at all times during its operation
- require training and requalification of ROs and SROs, and
- specify the minimum number of ROs and SROs for each shift.[15]

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[13] Based on an initial review of the Atomic Energy Act.

[14] In addition, Section 107 of the Atomic Energy Act, 42 USC § 2137, states that "[t]he Commission shall– a. prescribe uniform conditions for licensing individuals as operators of any of the various classes of production and utilization facilities licensed in this Act; b. determine the qualifications of such individuals; c. issue licenses to such individuals in such form as the Commission may prescribe; and d. suspend such licenses for violations of any provision of this Act or any rule or regulation issued thereunder whenever the Commission deems such action desirable"

[15] A single operating reactor must have at least 2 ROs and 2 SROs per shift. Typically, an operating reactor will have five shifts. Furthermore, licensees usually have more than the minimum number of ROs and SROs to account for absences due to illness, vacation, and turnover of personnel. Thus, for a single power reactor, it may be expected that a single power reactor may have about 30 licensed reactors. *See, e.g.*, Department of Energy, *Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding*

In addition, 10 CFR Part 55 contains extensive requirements for the licensing of ROs and SROs, and NUREG-1021 contains extensive guidance on *Operator License Examination Standards for Power Reactors*. For example, 10 CFR § 55.46 requires the construction and use of simulation facilities to train licensed operators.

On September 23, 2011, the Nuclear Energy Institute (NEI) issued a *Position Paper on Control Room Staffing for Small Reactors*. The purpose of the paper was to support NRC efforts to address and resolve policy issues identified by the NRC staff regarding staffing levels for small modular reactors (SMRs).

In SECY-11-0098, *Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities* (July 22, 2011), the NRC acknowledged that "[t]he number of licensed operating personnel that the rule prescribes are based on assumptions and operating experience from the operation of large light-water reactors"[16] (LWRs) and that those assumptions may not be appropriate for small module reactors (SMRs). As a result, the NRC stated that it:

> ..expects to use a two-step approach to address operator staffing requirements for SMRs. In the near-term, applicants can request exemptions to the current operator staffing requirements in 10 CFR 50.54(m) and the staff will review the request using existing or modified guidance. Once experience is gained, the staff would initiate the long-term solution which is to revise the regulations to provide specific control room staffing requirements for SMRs.[17]

NUREG-1791 contains *Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)* (July 2005). Although NUREG-1791 applies to requests for exemptions from the staffing requirements in § 50.54(m), Sections 1.3 and 1.4 of NUREG-1791 also recognize that other provisions in Section 50.54 and Part 55 might be impacted, and it provides a useful model for requesting exemptions from those provisions also. Additionally, Standard Review Plan (SRP) Chapter 18 and NUREG-0711, Rev. 3 (Nov. 2012) contain a *Human Factors Engineering Program Review Model* suitable for supporting an exemption request.[18]

For design certifications (DC), the NRC staff has identified two possible mechanisms for deviating from the operator staffing requirements in 10 CFR § 50.54(m). First, the DC applicant could justify different operator staffing levels and specify staffing levels in Tier 1 of the design certification. Alternatively, the DC applicant could provide the technical basis for different operator staffing levels in Tier 2, which could then be used by an applicant for a reactor license to request an exemption from § 50.54(m).[19]

Requirements for Advanced Reactor Designs (May, 27,2004), Table 3-5, ADAMS No. ML101820632. For multiple units at a site, § 50.54(m) increases the number of necessary ROs.

[16] SECY-11-0098, p. 2.

[17] Id., p. 3.

[18] The NRC staff's table on the status of policy issues applicable to advanced reactors states that the "existing version of SRP Chapter 18 and Revision 3 to NUREG 0711 (published November 2012) comprise adequate guidance for performing the exemption request evaluations" for licensed operators. *See* https://www.nrc.gov/reactors/new-reactors/smr.html#techPolicyIssues.

[19] NRC staff letter from Frank Akstulewicz to Thomas Bergman of NuScale dated January 16, 2016, p. 2.

B.2 Proposed Changes to NRC's Requirements for Operators

The two-step process described in SECY-11-0098 for determining operating staffing for SMRs appears to be equally appropriate for the issues surrounding micro reactors (*e.g.*, operator training and requalification including use of simulators, continuous presence of an operator in the control room, requirements for licensed operators to manipulate the reactor controls, as well as operator staffing requirements). The first set of applicants for design certification or licenses for micro-reactors may request an exemption from the requirements in 10 CFR § 50.54 and Part 55, or demonstrate compliance with these requirements in a different manner.

The applicant should perform an evaluation to determine whether operator actions are needed to protect public health and safety based upon the design of the plant.

- For applicants that demonstrates that no operator actions are needed to protect the public health and safety, then requirements applicable to reactor controls or operators should not be imposed. In such a case, the requirements in 10 CFR § 50.54 for the number of licensed operators on shift and for continuous presence of licensed operators in the control room, training and requalification programs, and simulators would likely not be warranted. It is noted that even if a design does not require any NRC licensed operators, the plant will likely still have at least one individual that is knowledgeable about the control system and would be able to manipulate the operator controls, either locally or remotely. The NRC may also need to allow for technology or non-licensed personnel to fulfill requirements related to Technical Specifications.

- If the evaluation concludes that one or more operator action is needed to protect the public health and safety, either full time or only for certain reactor operations or conditions, then the applicant should propose alternative operator requirements for the design. These alternative requirements should address the number of operators, need and duration for presence at the controls, training, requalification and simulators. The evaluation should consider whether having one or more licensed operators available within a certain period of time to man the control room would be sufficient to protect public health and safety.

- Due to advances in technology, a traditional control room may not be necessary. For micro-reactors that demonstrate the safety of the reactor can be assured without the need for operator action, and if an individual is unable to compromise the safety of the reactor through the manipulations of the controls, then there would be no need for requirements relating to the control room or for an operator-initiated shutdown. Therefore, requirements for control rooms, such as 10 CFR Part 50 Appendix A, General Design Criteria 19, may not be applicable to micro-reactors. The use of portable monitoring devices may also allow responsible personnel to monitor plant parameters and maintain operational control from either outside the control room or offsite during normal operations. Finally, to the extent that licensed operators are needed at micro-reactors, it is likely that their training and requalification could be substantially different (and less extensive) than that contemplated in Part 55 and NUREG-1021.

- The NRC should establish a policy or process for reviewing exemptions to 10 CFR § 50.54 and Part 55 to provide clarity to the first set of applicants for design certification or licenses for micro-reactors. It is noted that while historically exemptions requests were developed based upon the guidance in NUREG-1791, SRP Chapter 18 and NUREG-0711, micro-reactors are significantly different than the large LWRs for which the guidance was developed. Therefore, while the guidance may provide useful insights into the thought process, it need not be followed in order to submit an exemption request. Once experience is gained through the exemption process, the NRC should then consider engaging in rulemaking to augment § 50.54 and Part 55 to provide for the type of evaluation discussed above. In order to reflect the needs of micro-reactors, which are different from those for LWRs, the regulations in 10 CFR § 50.54 and Part 55 may need to be augmented to establish alternative requirements for reactors with automatic and/or remote operations/monitoring that do not require operators to protect the public health and safety. These requirements should be scalable to accommodate the variety of micro-reactors and their needs in the areas of operator licensing, training, and requalification applicable to all types of micro reactors.

Furthermore, since some micro-reactors may not have a control room, it may be beneficial to modify several regulations to refer to "reactor controls" rather than the "control room". Candidates include the following regulations: §§ 50.36(c)(ii)(A)(2)(ii)(A) dealing with limiting conditions for operation; 50.46a(a) dealing with controls for high point vents; and 50.67(b)(iii) dealing with protection against accident source terms.

To help inform the NRC's consideration of approaches for operators and reactor control for micro-reactors, detailed information should be developed on the automatic and remote operation features that are being included in these designs, including how these features will be designed to meet safety and cyber security requirements, and how they would be able to meet the intent of the regulations without the need for licensed operators or traditional control rooms. A generic methodology for micro-reactors to evaluate the need for operator actions for designs with automatic or remote operation features would also help to streamline the NRC review.

APPENDIX C: NRC RESIDENT INSPECTORS

The licensee is responsible for facility safety and compliance with regulatory requirements, and the NRC inspection requirements are designed to independently assess the licensee's fulfilment of those responsibilities. The NRC inspection program is performance-based, such that inspectors focus their attention on activities important to safety, and emphasize observing activities and the results of licensee programs over reviewing procedures or records. A key component of the NRC inspection program for large LWRs in operation today is the use of on-site resident inspectors. While this may make sense for a large nuclear power plant that is complex and contains a large number of safety-related SSCs, it is not necessary to assure public health and safety for a micro-reactor that is simple and has few if any safety related SSCs.

C.1 Existing Regulatory Requirements

The Nuclear Regulatory Commission (NRC) regulations do not require resident inspectors at nuclear power plants.[20]

The NRC Inspection Manual includes provisions for resident inspectors for light water reactors (LWRs).[21] It is NRC's practice to assign at least two resident inspectors for an operating reactor.[22] Multi-unit sites have at least two resident inspectors and sometimes more. Additionally, the Inspection Manual provides for resident inspectors at some of the fuel cycle facilities.[23]

The NRC inspection of research and test reactors is performed by inspectors from NRC Headquarters on an annual or biennial basis.[24] The NRC has not developed any inspection manual guidance on resident inspectors for micro reactors.

C.2 Proposal for NRC's Inspection of Micro-Reactors

The NRC should develop an inspection manual for micro-reactors that have very few activities that are relied on for safety. The inspection manual, or applicant proposed inspection guidelines, should focus on the use of periodic inspections (e.g., annually or biennially) and avoid the use of resident inspectors. The inspection guidelines should be developed to ensure the NRC has reasonable assurance that the licensee is complying with the requirements. These inspections are sufficient to provide oversight of micro-reactors. Other elements of the NRC's Reactor Oversight Program for power reactors, such as a significance determination process and performance indicators may not be necessary due to the simplicity, reliance on passive and inherent features, and the low potential consequences of these micro-reactors.

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[20] See, e.g., 10 CFR § 50.70. While this section states that a licensee shall make office space available for a full-time inspector and shall afford "any NRC resident inspector assigned to that site" unfettered access to the site, it does not actually require that the NRC utilize resident inspectors.

[21] *See, e.g.*, Inspection Manual Chapter (IMC) 2515, Light Water Reactor Inspection Program – Operations Phase (03/28/17), § 2515-11.01

[22] https://www.nrc.gov/reading-rm/basic-ref/glossary/resident-inspector.html.

[23] *See, e.g.*, IMC 2600, Appendix C, Fuel Cycle Resident Inspection Program (09/24/15) (for high enriched uranium facilities); IMC 2630, Mixed Oxide Fuel Fabrication Facility Construction Inspection Program (09/20/16), § 07.03; NRC Inspection Procedure (IP) 88135, Resident Inspection Program for Category I Fuel Cycle Facilities (02/07/14).

[24] *See* IMC 2545, Research and Test Reactor Inspection Program (06/23/04).

The inspection manual or applicant proposed inspection guidelines may be informed by the Inspection Manual Chapter (IMC) 2545 and its associated inspection procedures related to research and test reactors. While IMC-2545 is developed to meet the Section 104c of the Atomic Energy Act, 42 USC § 2134c direction that the NRC to impose only a “minimum amount of regulation”, which is focused solely on the regulation of research and test reactors, it is acknowledged that this philosophy is consistent with the NRC’s Principles of Good Regulation, specifically Efficiency. Thus, it is reasonable to expect that NRC inspections of micro-reactors would also adhere to the guidance of "the minimum amount of regulation ... to protect the public health and safety."

Prior to operation of the first micro reactor, the NRC should develop inspection procedures specifically for such reactors. The NRC’s inspection manual and procedures should be performance based and should be scalable to accommodate a variety of micro-reactors. Micro-reactor inspection procedures may be informed by inspection procedures for research and test reactors, however, important differences between micro-reactors and research and test reactors may necessitate different approaches. For example, Inspection Procedure 69005, Class I Non-Power Reactor Experiments, is largely irrelevant to micro reactors that are intended for power production rather than research and testing.

The NRC oversight of construction activities is expected to focus most heavily on supply chain inspections, owing to most of the construction work being performed in factories, with very little on-site work. For Part 52 licensees, it is expected that micro-reactors would have significantly fewer ITAAC. Furthermore, the construction schedule could be as short as 6 months, which would be much shorter than the construction timelines anticipated when Part 52 was created.

To help inform the NRC’s consideration of micro-reactor oversight, more detailed information should be developed on the activities at micro-reactors that are relied on for safety, which could include recommendations for the scope and frequency of inspections that would be appropriate based on the safety significance.

APPENDIX D: EMERGENCY PREPAREDNESS

The Nuclear Regulatory Commission (NRC) has prepared a draft proposed rule on emergency preparedness (EP) for small modular reactors and other new technologies. [25] The industry believes the scope of this rule is sufficiently broad to encompass micro-reactors, and the elements of this rule are a substantial improvement over existing requirements in Appendix E to Part 50 and associated guidance. In particular, the draft proposed rule embodies an approach that is considerably more performance-based, risk-informed, and consequence-oriented than the current EP regulatory framework. For example, it does not require offsite radiological emergency planning if doses at the site boundary do not exceed 1 rem TEDE,[26] which should be suitable for micro reactors given the expected relatively small source terms. The draft proposed rule does list required emergency response functions in draft 10 CFR § 50.160(c)(1)(iii) that must be addressed in an onsite emergency plan (and EP program). However, neither the draft proposed rule nor the associated guidance in draft regulatory guide DG-1350 "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," explicitly refer to micro reactors, and there may be additional changes that are necessary to support the licensing of micro-reactor facilities.

D.1 Existing Regulatory Requirements

The emergency preparedness (EP) regulations of the U.S. Nuclear Regulatory Commission (NRC) are primarily focused on large light water reactor (LWR) facilities. For example, 10 CFR 50.47, "Emergency plans," requires an Emergency Planning Zone (EPZ) for nuclear power plants that consists of an area about 10 miles in radius. The same requirement is found in 10 CFR 50, Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities." Footnote 1 in 10 CFR 50, Appendix E states, "EPZs for power reactors are discussed in NUREG–0396; EPA 520/1–78–016, 'Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants,' December 1978." In turn, NUREG-0396 uses data related to severe accidents in large LWRs as the basis for a 10-mile EPZ.[27]

While § 50.47(c)(2) states that "[t]he size of the EPZs also may be determined on a case-by-case basis for gas-cooled nuclear reactors and for reactors with an authorized power level less than 250 MW thermal," it does not obviate the need for EPZs. Similarly, the emergency plan requirements described in Appendix E to Part 50 apply generally to reactors, while recognizing:

> The potential radiological hazards to the public associated with the operation of research and test reactors and fuel facilities licensed under 10 CFR parts 50 and 70 involve considerations different than those associated with nuclear power reactors. Consequently, the size of Emergency Planning Zones (EPZs) for facilities other than power reactors and the degree to which compliance with the requirements of this section and sections II, III, IV, and V of this appendix as necessary will be determined on a case-by-case basis.

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[25] "Emergency Preparedness Requirements for Small Modular Reactors and Other New Technologies," RIN 3150-AJ68, Docket ID, NRC-2015-0225
[26] *See*, *e.g.*, draft proposed rule, §§ 50.33(g)(2) and 50.160(c)(1)(iii)(B).
[27] *See* NUREG-0396, *Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants* (December 1978), Appendix I.

The NRC's EP guidance for power reactors is likewise focused on large LWR facilities. For example, NRC's primary EP guidance found in NUREG-0654, Rev. 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," (Nov. 1980) applies to commercial power reactors, with little or no recognition that smaller reactors may pose less of a risk warranting fewer EP requirements.[28]

Separately, Congress has passed legislation requiring the NRC to take action to facilitate licensing of advanced reactors. Section 103(a) of the Nuclear Innovation and Modernization Act, Public Law No: 115-439; Jan. 13, 2019, states:

> Not later than December 31, 2027, the Commission shall complete a rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications.

That section also states:

> Not later than 2 years after the date of enactment of this Act, the Commission shall develop and implement, where appropriate, strategies for the increased use of risk-informed, performance-based licensing evaluation techniques and guidance for commercial advanced nuclear reactors within the existing regulatory framework, including evaluation techniques and guidance for the resolution of the following: … emergency preparedness.

In summary, advances in reactor design and safety research are not reflected in the existing EP regulatory framework, and the framework is insufficiently risk-informed and performance-based. Absent any changes, existing EP regulations and guidance would impose regulatory burdens on the applicants and licensees of advanced reactor facilities that are not necessary to protect the public health and safety. The NRC staff also reached this conclusion as discussed in "Final Regulatory Basis - Rulemaking for Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated September 2017.[29]

As directed by the Commission in SRM-SECY-16-0069, "Staff Requirements – SECY-16-0069 – Rulemaking Plan on Emergency Preparedness for Small Modular Reactors and Other New Technologies," the NRC staff has undertaken a rulemaking to update the EP regulatory framework. SECY-18-0103, "Proposed Rule: Emergency Preparedness for Small Modular Reactors and other New Technologies," contains the draft proposed rule and states that the rule scope includes small modular reactors (SMRs) and "other new technologies (ONTs), such as non-light-water reactors (non-LWRs) and certain non-power production or utilization facilities (NPUFs)." In conjunction with this rulemaking, the NRC is also planning to issue an associated regulatory guide (DG-1350) providing guidance for implementing the rule.[30] The

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[28] *See* NUREG-0654, Section I.C and footnote 6, which states in part that "small water cooled power reactors {less than 250 MWt) and the Fort St. Vrain gas cooled reactor may use a plume exposure emergency planning zone of about 5 miles in radius and an ingestion pathway emergency planning zone of about 30 miles in radius."
[29] The final regulatory basis is available in ADAMS as ML17206A265.
[30] A draft of DG-1350, *Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities*, is available in ADAMS at ML18213A284.

contents of SECY-18-0103 are used as a baseline for the evaluation below and the determination as to whether changes should be made to accommodate micro reactors.[31]

D.2 Proposal for Emergency Preparedness for Micro-Reactors

For micro-reactors that can demonstrate that the potential consequences of accidents, even for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public, it is expected that emergency preparedness will largely focus on the onsite response. Consequences of anticipated events at micro-reactors are expected to be small enough that one or more of the listed emergency response functions may not be necessary to protect onsite emergency workers or the public.

While the draft rule 10 CFR 50.160 appears to be flexible enough to accommodate the licensing of micro-reactors, the NRC should ensure that DG-1350 fully contemplates micro-reactor designs with extremely small potential consequences. This includes adopting approaches similar to those in Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors and other Non-Power Production and Utilization Facilities" and NUREG-0849, "Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors," that were developed for research and test reactors. In the NRC's Regulatory Basis for the rulemaking (ML17206A265), the NRC highlights the following points about non-power reactors, which may be equally applicable to some micro-reactors:

> *"While non-power production or utilization facilities must meet the emergency planning requirements of 10 CFR 50.34(a)(10), 50.34(b)(6)(v), 50.54(q), and Appendix E to 10 CFR Part 50, the requirements of 10 CFR 50.47 do not apply to these facilities. Additionally, in section I.3 of Appendix E to 10 CFR Part 50, the NRC differentiates between emergency planning requirements for nuclear power reactors and non-power facilities, stating:*
>
> *"The potential radiological hazards to the public associated with the operation of research and test reactors and fuel facilities licensed under 10 CFR parts 50 and 70 ["Domestic Licensing of Special Nuclear Material"] involve considerations different than those associated with nuclear power reactors. Consequently, the size of Emergency Planning Zones (EPZs) for facilities other than power reactors and the degree to which compliance with the requirements of this section and sections II, III, IV, and V of this appendix as necessary will be determined on a case-by-case basis.*
>
> *Furthermore, Footnote 2 of Appendix E allows the use of Regulatory Guide (RG) 2.6, "Emergency Planning for Research and Test Reactors" (Ref. 21) for the development and evaluation of emergency response plans at non-power reactors."*

To help inform the NRC's consideration of emergency preparedness for micro-reactors, a detailed description of the potential accidents and consequences, and a generic micro-reactor EP plan should be developed.

[31] This paper focuses on micro reactors, and is not intended to provide comments on the draft proposed rulemaking in general.

APPENDIX E: PHYSICAL SECURITY

As directed by memorandum "Staff Requirements - SECY-18-0076 - Options and Recommendations for Physical Security for Advanced Reactors," dated November 19, 2018, the NRC staff has undertaken a rulemaking to establish physical security requirements appropriate for advanced reactors. As part of this rulemaking, the staff prepared a draft regulatory basis[32] for the rule and made it available for public comment.[33] The industry supports the use of the performance-based, technology-neutral and consequence-oriented approach described in the draft regulatory basis for developing a new physical security framework for advanced reactors. The use of the term "advanced reactor" in the draft regulatory basis appears to be sufficiently broad to encompass micro-reactors. Nevertheless, given their relatively small source terms and radiological consequences expected for micro-reactors, the industry believes additional changes are likely warranted to avoid unnecessary regulatory burden.

E.1 Existing Regulatory Requirements

The security regulations of the U.S. Nuclear Regulatory Commission (NRC) applicable to licensed production and utilizations facilities are contained in 10 CFR Part 73, "Physical Protection of Plants and Materials." Those regulations are focused on protecting against acts of radiological sabotage and preventing theft or diversion of special nuclear material.[34] Relevant to the topic of this paper, the regulations directed at physical security requirements for power reactors are presented in 10 CFR 73.55. It is clear from NRC's "Power Reactor Security Requirements; Final Rule," [35] this regulation is intended for large LWR facilities.

The physical security regulations in § 73.55, "Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage," are not suited to the new types of power reactor technologies currently under development. This point was discussed in NEI white paper, "Proposed Physical Security Requirements for Advanced Reactor Technologies," dated December 14, 2016. As noted in the white paper, "Absent a change to existing regulations, advanced reactor technologies will be subject to the existing physical security requirements delineated in § 73.55, which would impose an unnecessary regulatory burden on applicants and licensees. Compliance with § 73.55 requirements will diminish the cost competitiveness of advanced reactor technologies, thus hindering their development and deployment." This same concern also applies to micro reactors.

Congress passed legislation requiring the NRC to take action to facilitate licensing of advanced reactors, including modification of its security requirements. Section 103(a) of the Nuclear Innovation and Modernization Act, Public Law No: 115-439; Jan. 13, 2019, states:

> Not later than 2 years after the date of enactment of this Act, the Commission shall develop and implement, where appropriate, strategies for the increased use of risk-informed, performance-based licensing evaluation techniques and guidance for commercial advanced nuclear reactors within the existing regulatory framework, including evaluation techniques and guidance for the

[32] "Rulemaking for Physical Security for Advanced Reactors - Regulatory Basis for Public Comment," dated July 2019

[33] Refer to Regulations.gov, Docket ID NRC-2017-0227

[34] *See, e.g.* NRC's draft *Regulatory Basis for Rulemaking for Physical Security for Advanced Reactors* (July 2019), p. 1-1.

[35] 74 Fed. Reg. 13,925 (March 27, 2009)

> resolution of the following: (A) Applicable policy issues identified during the course of review by the Commission of a commercial advanced nuclear reactor licensing application. . . .

The NRC's list of policy issues for SMRs and non-LWRs includes security and safeguard issues.[36] Some micro-reactors may use fuel at enrichments and quantities that would meet the criteria of Category II special nuclear material. There is currently ambiguity in the requirements to protect Category II material, as highlighted in a recent NEI report *"Addressing the Challenges with Establishing the Infrastructure for the front-end of the Fuel Cycle for Advanced Reactors."* The lack of clarity could impact the development of the design of and security planning for micro-reactors. We encourage the NRC to continue working with DOE expeditiously to finalize a consistent approach for addressing material attractiveness, and for the NRC to continue with efforts to clarify the regulatory framework for the protection of Category II special nuclear material.

In July 2019, the NRC issued a draft "Regulatory Basis for Rulemaking for Physical Security for Advanced Reactors,"[37] for public comment. The draft regulatory basis identifies plans for a limited-scope rulemaking that would provide voluntary, performance-based alternatives to a limited number of current physical security requirements, primarily those affecting the number of armed responders and requirements for onsite secondary alarm stations.[38] The draft regulatory basis also states that "during the limited-scope rulemaking, the staff could also identify other requirements that may be eliminated or modified to reduce the potential number of exemptions that would need to be processed for this class of facilities." We believe that micro reactors are a rule area that should be explored to determine if there are other physical security requirements that may be eliminated or modified. The recommendations presented below are based on a review of the draft regulatory basis and, if included in the final rule, would facilitate the licensing of micro reactor designs.[39]

The draft regulatory basis proposes the use of three performance measures to determine whether an applicant may qualify for alternative physical security requirements. All three measures reference the offsite dose limits in 10 CFR 50.34, "Contents of Applications; Technical Information," and 10 CFR 52.79, "Contents of Applications; Technical Information in Final Safety Analysis Report," as performance-based consequence-oriented criteria, and are shown below.

> 1. The radiological consequences from a hypothetical, unmitigated event involving the loss of engineered systems for decay heat removal and possible breaches in physical structures surrounding the reactor, spent fuel, and other inventories of radioactive materials result in offsite doses below the reference values defined in 10 CFR 50.34 and 52.79 (e.g., no definable target sets of equipment or operator actions that if prevented from performing their intended safety function or prevented from being accomplished, would likely result in offsite doses exceeding the cited reference values);
>
> 2. The plant features necessary to mitigate an event and maintain offsite doses below the reference values in 10 CFR 50.34 and 52.79 cannot reasonably be compromised by

[36] *See* https://www.nrc.gov/reactors/new-reactors/smr.html#techPolicyIssues
[37] This draft regulatory basis is available in ADAMS as ML 19099A017.
[38] *Id.*, p. 3-3.
[39] This paper focuses on micro reactors, and is not intended to provide comments on the draft regulatory basis in general. Thus, for example, there may be changes in the provisions in the draft regulatory basis that would equally benefit advanced reactors and micro reactors. This paper does not discuss such changes, and instead focuses on security issues unique to micro reactors.

the Design-basis threat (DBT) for radiological sabotage (e.g., no achievable target set resulting in offsite doses exceeding the cited reference values given the design features and security features incorporated into a specific advanced reactor facility); or

3. Plant features include inherent reactor characteristics combined with engineered safety and security features that allow for facility recovery and mitigation strategy implementation if a target set is compromised, destroyed, or rendered nonfunctional, such that offsite radiological consequences are maintained below the reference values defined in 10 CFR 50.34 and 52.79 (e.g., a reactor design with a large heat capacity and slow progression from loss of safety equipment to degradation of fission product barriers and release of radionuclides from the facility). Facility recovery and mitigation strategies may, where feasible, include support from offsite resources.[40]

Research and test reactors, which are more similar to micro-reactors in terms of potential consequences, are regulated under 10 CFR 73.60. One of the biggest differences between RTRs and large commercial reactors is that there is no design basis threat for RTRs.

E.2 Proposal for Physical Security for Micro-Reactors

For micro-reactors that can demonstrate that the potential consequences of accidents for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public, staff's ongoing rulemaking activities for the physical security for SMRs does not address all of the needed changes. As a result, absent additional changes to security requirements there would be considerable regulatory burden beyond that necessary to provide reasonable assurance of adequate protection of the public health and safety.

Revising security requirements for micro-reactors, for which an unmitigated design basis threat would result in offsite doses below the reference values defined in 10 CFR 50.34 and 52.79, should be accomplished through a more comprehensive consideration of alternatives to the requirements in 10 CFR 73.55 than has been proposed in the draft regulatory basis for a limited scope rulemaking. In the absence of a more comprehensive rulemaking and development of more appropriate guidance for micro-reactor physical security, applicants should expect to propose alternatives to the requirements, or alternative methods to meet the requirements. The potential consequences of micro-reactors are expected to be similar to research and test reactors, for which there is no DBT. Therefore, establishment of the requirements that are applicable to micro-reactors should consider the requirements in 10 CFR 73.60, "Additional requirements for physical protection at nonpower reactors," and 10 CFR 73.67 "Licensee fixed site and in-transit requirements for the physical protection of special nuclear material of moderate and low strategic significance." applicable to nonpower reactors. Consideration should also be given to alternatives to requirements to protect against theft and diversion and cyber security.

The Atomic Energy Act has requirements for security response evaluations and the design basis threat (Sections 170D and 170E), and grants the NRC discretion to determine the classes of reactors to which these requirements should apply.[41] Micro-reactors will have very low radionuclide inventories as compared to large light-water reactors, and may not rely on active safety functions or human actions to

[40] Draft regulatory basis, p. 4-5.
[41] Based on an initial review of the Atomic Energy Act.

protect the public health and safety. Micro-reactors are also expected to be designed and operated so that material is not easily handled or dispersed, and is protected against potential radiological theft or exposure. Micro-reactors are also expected to include a robust design in order to protect the public health and safety from potential accidents.

For micro-reactors that, even under the most severe scenarios, where the potential offsite consequences from an attack does not result in undue risks to public health and safety should not be required to put in place additional design features or protective actions specifically to protect against the DBT. From a regulatory perspective, this outcome could be realized by either determining the prescriptive requirements related to protecting against the DBT are not applicable to micro-reactors, or more similar to RTRs.

For micro-reactors that meet the above conditions, the security approach should be focused on the protection of nuclear material from theft and diversion, and would likely include the following. This security approach for micro-reactor security should utilize a graded approach based on the amount of nuclear fuel and the potential health and safety consequences to the public.

- Screening and training of personnel
- Access controls
- Intrusion detection
- Physical barriers to protect against theft and diversion
- Communications with law enforcement

It is noted that human actions may not be necessary to perform these functions, as they could be performed by automatic plant features.

Micro-reactors that meet the above conditions should not need to meet prescriptive requirements in 10 CFR 73.55 related to protection against the DBT, for example:

- The physical protection program:
    - Does not need to protect against the DBT or prevent significant core damage and spent fuel sabotage;
    - Does not need to have the capability to interdict or neutralize threats;
    - Does not need to establish, maintain and implement a performance evaluation program or force-on-force evaluation to demonstrate and assess the effectiveness of armed responders and armed security officers;
    - May not need an insider mitigation program;
    - May not need a cyber security program;
    - Does not need to meet specific requirements for the positions or number of personnel in the security organization;
    - May not require an isolation zone, protected area or vital areas;
    - Does not require vehicle control measures to protect against the design basis threat; and
    - Does not require armed responders, armed security personnel, or associated requirements for training or firearms

- Physical barriers:
  - Do not need to be designed and constructed with the purpose of protecting against the design basis threat; and
  - May not be needed to provide deterrence, or delay, or be necessary to implement the licensee's protective strategy, in fact the licensee may not need a protective strategy
  - For the reactor control room, or reactor control location if there is no control room, do not need bullet resisting physical barriers.
- Personnel assigned security functions:
  - May have additional on-shift duties;
  - May be anywhere on-site or in specified off-site locations; and
  - Do not need to be armed.

Finally, micro-reactors are expected to have fuel characteristics and physical barriers that protect against the theft and diversion of nuclear material. The material of concern is not expected to be readily separable from other radioactive material and is expected to be self-protecting during operations. It is noted that additional security measures are likely to be needed when the fuel is not self-protecting. Also, the fuel is expected to be contained within several physical barriers requiring a significant amount of time and specialized heavy machinery to move, making it virtually impossible to quickly access and remove the fuel. Consideration should also be given to alternatives to requirements for cyber security for micro-reactors that meet the above conditions.

To help inform the NRC's consideration of security for micro-reactors, a generic methodology should be developed for the assessment of the consequences from a worst-case accident or unmitigated security threat, and develop a generic micro-reactor security plan.

APPENDIX F: AIRCRAFT IMPACT ASSESSMENT

For micro-reactors with very small footprints and profiles, aircraft impacts are highly unlikely because their small size makes them extremely difficult to hit with a large commercial aircraft. These reactors are also unattractive targets for terrorists because they are not high-value targets whose destruction would cause mass-casualties. For micro-reactors that can demonstrate that the potential consequences of accidents, even for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public, are also expected to not pose a hazard to the public health and safety from a potential aircraft impact. For micro-reactors that meet these conditions, the NRC should consider alternative approaches to demonstrating compliance with the Aircraft Impact Rule.

F.1 Existing Regulatory Requirements

The malevolent use of commercial aircraft to attack U.S. iconic buildings resulted in NRC issuing Order EA-02-026, Order for Interim Safeguards and Security Compensatory Measures (February 2002). Section B.5.b of this Order required the existing NPP fleet to adopt mitigation strategies using readily-available resources to maintain or restore core cooling, containment, and SFP cooling capabilities to cope with loss of large areas of the facility due to large fires and explosions from any cause, including beyond-design-basis aircraft impacts.

The impact of a large, commercial aircraft is a beyond-design-basis event and the stringent requirements that apply to the design, construction, testing, operation, and maintenance of design features and functional capabilities for design basis events do not apply. This position is based, in part, on results of NRC aircraft impact studies performed in response to the September 2001 events. These detailed studies confirmed the low likelihood of an aircraft impact both damaging the reactor core and releasing radioactivity that could affect public health and safety. In its Staff Requirements Memorandum (SRM) approving the AIA Rule, the NRC Commission agreed that the impact of a commercial airliner is a beyond-design-basis event and therefore not necessary for reasonable assurance of adequate protection to public health and safety.

In March 2009, NRC published new requirements (known as the 'AIA Rule') relating to aircraft impact (10 CFR Part 50.150-Aircraft Impact Assessment). The AIA Rule applies to applicants for new construction permits (CPs), new operating licenses that reference a new CP, new standard design certifications (DCs) and new standard design approvals (SDAs) issued after July 13, 2009. Applicants meeting these criteria are required to perform a design-specific assessment of the effects on the facility of the impact of a large, commercial aircraft. Using realistic analyses, applicants should identify and incorporate into the design those design features and functional capabilities to show that, with reduced use of operator actions:

(i) The reactor core remains cooled, or the containment remains intact; and
(ii) Spent fuel cooling or spent fuel pool integrity is maintained.

For the purpose providing implementing guidance for the AIA Rule, NEI developed NEI-07-13, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs". The guidance document was a collaborative NRC/NEI effort and considered insights gained from NRC and industry assessments of operating and new reactor designs.

In 2011, NRC issued RG 1.217, "Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts", which wholly-endorsed NEI 07-13 as an acceptable method for performing aircraft impact assessments and satisfying required NRC regulations (i.e., 10 CFR 50.150). Since 2009, all new reactor designs have referenced RG 1.217 and NEI 07-13 as the method for performing aircraft impact assessments.

F.2 Proposal for Aircraft Impact Assessment for Micro-Reactors

A primary driver for the current approaches to designing nuclear reactors to withstand an aircraft impact is the fact that the consequences of such an impact could pose a hazard to the public health and safety. This consideration drives current plants to ensure that the reactor core remains cooled, or the containment remains intact, and spent fuel cooling or spent fuel pool integrity is maintained.

For micro-reactors that are very small, such that it is highly unlikely that an aircraft could impact the micro-reactor building or result in damage the fuel, and which have such low radionuclide inventories that a potential aircraft impact is unlikely to pose a substantial hazard to the public health and safety, it is expected that the unmitigated consequences of an aircraft impact on a micro-reactor would not lead to a significant adverse impact on the health or safety of the public. For these micro-reactors, the existing regulations on aircraft impact would result in unnecessary regulatory burden.

Micro-reactors that meet the above conditions would meet the intent of 10 CFR Part 50.150 to adequately protect the public health and safety from the consequences of an aircraft impact without the need for other means of defense-in-depth. Furthermore, these designs would likely not need to meet the acceptance criteria of 10 CFR Part 50.150 (i.e., the reactor core does not need to remain cooled or the containment remain intact and the spent fuel cooling or spent fuel pool integrity is not needed to be maintained in order to meet NRC dose requirement in 10 CFR 50.34) in order to adequately protect the public health and safety. Therefore, it would also be unnecessary for a micro-reactor to perform a realistic analysis of an aircraft impact, if such an impact could not pose a substantial hazard to the public health and safety.

While changes to 10 CFR 50.150 to implement such a consequence-oriented standard may be appropriate, in the meantime micro-reactors that meet the above conditions should be eligible for an exemption to 10 CFR Part 50.150, or to justify that they meet the intent of the regulation in a different manner.

To help inform the NRC's consideration of aircraft impacts for micro-reactors, a generic assessment should be performed on the likelihood of a commercial aircraft impact on a micro-reactor and the potential consequences of such an impact.