NON-LIGHT-WATER REACTOR IMPLEMENTATION ACTION PLAN—PROGRESS SUMMARY AND FUTURE PLANS

Enclosure

1.0 Introduction

This enclosure summarizes activities underway and planned by the U.S. Nuclear Regulatory Commission (NRC) staff to make the safe use of advanced nuclear technology possible. This enclosure covers progress made during calendar year (CY) 2021, in each of six strategic areas:

(1) staff development and knowledge management (KM)
(2) analytical tools
(3) regulatory framework
(4) consensus codes and standards
(5) resolution of policy issues
(6) communications

Figure 1 shows the broad range of activities underway including many that have been completed. Checkmarks indicate completed activities. All other activities have been initiated and are under implementation progress.

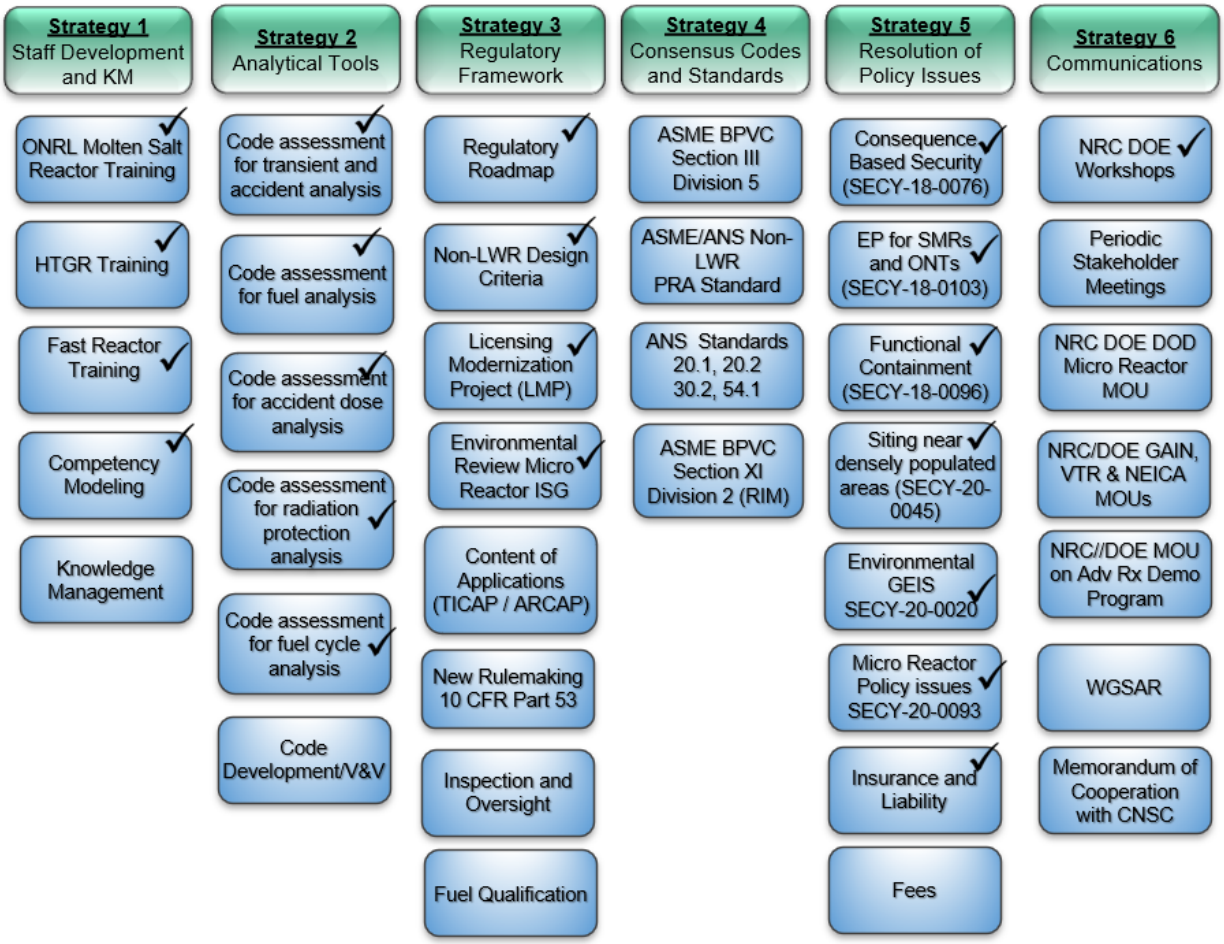

Figure 1 Implementation action plan activities

Significant accomplishments in 2021 include the following:

- The NRC staff submitted the draft final rule and associated guidance on emergency preparedness (EP) for small modular reactors (SMRs) and other new technologies (ONTs) that would amend the NRC's regulations to add alternative EP requirements for facilities such as non-LWRs and non-power production or utilization facilities for Commission consideration on January 3, 2022.

- The NRC staff developed a draft generic environmental impact statement (GEIS) for advanced reactors and an associated proposed rule package, which it submitted to the Commission on November 29, 2021 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21222A044).

- The NRC staff completed its acceptance review of the Kairos Power Fluoride Salt Cooled, High Temperature Non-Power Reactor (Hermes) Construction Permit (CP) application and docketed the application for detailed review on November 29, 2021.

- The NRC staff completed, throughout 2021, the review of six topical reports from Kairos supporting the Hermes CP application review.

- The NRC staff released preliminary proposed rule language, throughout 2021, for all subparts of the future Title 10 of the *Code of Federal Regulations* (10 CFR) Part 53, "Licensing and Regulation of Advanced Nuclear Reactors." It held over 20 public meetings with external stakeholders and the Advisory Committee on Reactor Safeguards (ACRS).

- The NRC staff held public meetings, throughout 2021, to obtain stakeholder feedback on the advanced reactors limited scope rulemaking, published revised draft rule text, and developed revisions to DG-1365, "Guidance for Alternative Physical Security Requirements for Small Modular Reactors and Non-Light-Water Reactors" and DG-5071 as Revision 2 of Regulatory Guide (RG) 5.81, "Target Set Identification and Development for Nuclear Power Reactors."

- The NRC staff issued for public comment the draft NUREG-2159, Revision 1, "Acceptable Standard Format and Content for the Fundamental Nuclear Material Control Plan Required for Special Nuclear Material of Moderate Strategic Significance" (86 FR 52926; September 23, 2021; ADAMS Accession No. ML21263A119).

- The NRC participated in four tabletop exercises with the industry to demonstrate the use of the Technology Inclusive Content of Application Project (TICAP) draft guidance to develop portions of the license applications for the Westinghouse Electric Company eVinci microreactor design[1], the TerraPower Molten Chloride Reactor Experiment design[2], the X Energy LLC (X energy) Xe 100 high temperature gas cooled reactor design[3], and the Versatile Test Reactor sodium cooled metallic fueled pool type fast reactor design[4].

[1] See ADAMS Accession No. ML21272A303
[2] See ADAMS Accession No. ML21228A222
[3] See ADAMS Accession No. ML21217A086
[4] See ADAMS Accession No. ML21272A338

- The NRC staff issued in September 2021 a draft white paper outlining optional strategies for streamlining the licensing of micro-reactors (ADAMS Accession No. ML21328A189).

- The NRC staff developed DG-1383, "Acceptability of ASME Code, Section XI, Division 2, 'Requirement for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants,' for Non-light Water Reactors," which it issued for public comment in September 2021 (ADAMS Accession No. ML21120A185). DG-1383 endorses the ASME Boiler and Pressure Vessel Code (BPVC), Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Division 2, "Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants" (BPVC-XI-2). The associated regulatory analysis and FR notice can be found under ADAMS Accession No. ML21120A180 (package).

- The NRC cooperated with Brookhaven National Laboratory to issue in September 2021 a report on scalable human factors engineering (HFE) technical review strategies (ADAMS Accession No. ML21266A192).

- The NRC staff hosted in September the 2021 NRC Standards Forum to facilitate the identification of needed consensus codes and standards and to explore collaboration to accelerate their development. This forum focused on recent developments in codes and standards for advanced reactors and the regulatory approach for advanced manufacturing technologies (ADAMS Accession No. ML21229A263).

- The NRC staff published for public comment, in August 2021, DG-1380, "Acceptability of ASME Code, Section III, Division 5, 'High Temperature Reactors'" (ADAMS Accession No. ML21091A276), and the draft NUREG-2245, "Technical Review of the 2017 Edition of ASME Code, Section III, Division 5, 'High Temperature Reactors'" (ADAMS Accession No. ML21223A097).

- The NRC staff produced SECY-21-0072, "United States Nuclear Regulatory Commission's 2021 Report to Congress on the Price-Anderson Act," and submitted it for Commission consideration on August 2, 2021 ADAMS Accession No. ML21158A304. The NRC submitted NUREG/CR-7293 "The Price-Anderson Act: 2021 Report to Congress Public Liability Insurance and Indemnity Requirements for an Evolving Commercial Nuclear Industry" to Congress in December 2021 (ADAMS Accession No. ML21336A323).

- The NRC staff issued in July 2021 an updated draft white paper to inform advanced reactor applicants about the applicability of existing regulations to non-LWRs (ADAMS Accession No. ML21175A287).

- The NRC staff published in July 2021 draft NUREG titled "Fuel Qualification for Molten Salt Reactors" in cooperation with Oak Ridge National Laboratory (ORNL), which supports development of an efficient, appropriate methodology or process for liquid salt fuel system qualification (ADAMS Accession No. ML21245A493).

- The NRC staff developed reports for the appropriate congressional committees on (1) completing a rulemaking to establish a technology-inclusive regulatory framework for optional use by commercial advanced nuclear reactor technologies in new reactor license applications and ensuring that the agency has adequate expertise to support the

evaluation of commercial advanced reactor license applications, in accordance with Section 103(e) of NEIMA in July 2021 (ADAMS Accession No. ML21109A263 (package)), and (2) regulatory preparedness to support commercial availability of high assay low enriched uranium (HALEU) in December 2021 (ADAMS Accession No. ML21323A151).

- The NRC staff issued for public comment on June 30, 2021 the draft NUREG-2246, "Fuel Qualification for Advanced Reactors," which contains a proposed fuel qualification methodology as guidance for non-light-water reactor (non-LWR) developers on fuel qualification under the Nuclear Energy Innovation and Modernization Act (NEIMA), passed by Congress in 2019 (Public Law 115-439). This document is available in Volume 86 of the *Federal Register* (FR), page 34794 (86 FR 34794; June 30, 2021), and under ADAMS Accession No. ML21168A063.

- The NRC approved on June 11, 2021 Centrus Energy Corporation's license amendment request to produce high-assay low-enriched uranium (HALEU) at its Piketon, OH, enrichment facility (ADAMS Accession No. ML21138A827).

- The NRC staff collaborated with the Canadian Nuclear Safety Commission (CNSC) to issue in June and August 2021 the first two joint reports under the memorandum of cooperation on advanced reactor and SMR technical review approaches and pre-application activities. The June report was on the X-energy reactor pressure vessel construction code assessment (ADAMS Accession No. ML21166A304) and the August report was on comparing the U.S. Licensing Modernization Project (LMP) with the Canadian regulatory approach (ADAMS Accession No. ML21225A101).

- In collaboration with NUMARK Associates, Inc. and Oak Ridge National Laboratory (ORNL), the NRC staff issued in May 2021 a series of technical reports on materials, chemistry, and component integrity, which addressed molten salt chemistry, salt compatibility with high-temperature materials, high-temperature corrosion, and graphite (ADAMS Accession Nos. ML21116A231 and ML21109A123).

- The NRC staff issued in May 2021 a draft white paper to inform advanced reactor developers of the benefits of robust pre-application engagement to optimize both safety and environmental application reviews (ADAMS Accession No. ML21145A106).

- The NRC staff issued in April 2021 the white paper "Preliminary Options for a Regulatory Framework for Fusion Energy Systems" to support interactions with the ACRS and to summarize information previously shared with stakeholders during public meetings (ADAMS Accession No. ML21118A081).

- The NRC staff issued in March 2021 a Technical Letter Report (TLR)-RES/DE/CIB-CMB/2021-05, "Status of Advanced Non-light Water Reactor Research Activities: Materials, Chemistry, and Component Integrity" (ADAMS Accession No. ML21088A013).

- The NRC staff published on February 26, 2021 a final technology-inclusive, risk-informed, and performance-based (RIPB) design review guide for instrumentation and controls systems for advanced reactors (ADAMS Accession No. ML21011A140).

- The NRC staff issued on January 21, 2021 seven technical reports on operating experience and potential challenges for the transportation, storage, and disposal of advanced reactor fuel types (ADAMS Accession No. ML20184A143 (package)). The topic areas are: (1) Review of Operating Experience for Transportation of Fresh (Unirradiated) Advanced Reactor Fuel Types; (2) Potential Challenges with Transportation of Fresh (Unirradiated) Advanced Reactor Fuel Types; (3) Storage Experience with Spent (Irradiated) Advanced Reactor Fuel Types; (4) Potential Challenges with Storage of Spent (Irradiated) Advanced Reactor Fuel Types; (5) Transportation Experience and Potential Challenges with Transportation of Spent (Irradiated) Advanced Reactor Fuel Types; (6) Disposal Options and Potential Challenges to Waste Packages and Waste Forms in Disposal of Spent (Irradiated) Advanced Reactor Fuel Types; and (7) Information Gaps and Potential Information Needs Associated with Transportation of Fresh (Unirradiated) Advanced Reactor Fuel Type.

- The NRC staff issued on January 13, 2021 the draft white paper "Demonstrating the Acceptability of Probabilistic Risk Assessment Results Used to Support Advanced Non-light Water Reactor Plant Licensing," (ADAMS Accession No. ML21015A434). It also issued for public comment the (preliminary) RG 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-light Water Reactor Risk-Informed Activities" (ADAMS Accession No. ML21246A216), which endorses the American Society of Mechanical Engineers (ASME)/American Nuclear Society (ANS) standard ASME/ANS RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-light Water Reactor Nuclear Power Plants." The NRC staff has taken into consideration ACRS and public comments and will be issuing RG 1.247, for trial use in March 2022.

- The NRC staff briefed the ACRS Full Committee and the Subcommittees on Future Plant Designs, Metallurgy & Reactor Fuels, and Kairos Power Licensing during 22 separate meetings in 2021. The topics covered included the LMP; Advanced Reactor Content of Application Project (ARCAP) and TICAP guidance development; Advanced Reactor Computer Codes; non-LWR probabilistic risk assessment (PRA) acceptability; fuel qualification for advanced reactors; Molten Salt Reactor Fuel Qualification; RIPB human-system considerations for advanced reactors; Part 53 Rulemaking; Draft Final Rule for EP for SMRs and ONT; Kairos Topical Report on Fuel Performance; Kairos Topical Report on Mechanistic Source Term Methodology; Kairos design; Endorsement of ASME Section III, Division 5, "High Temperature Reactors"; and fusion technologies.

- The NRC chairs the International Atomic Energy Agency (IAEA) SMR Regulators' Forum. In 2021, the forum issued several reports on licensing, safety analysis, and manufacturing oversight of SMRs.

- The NRC chairs the Nuclear Energy Agency's (NEA's) Working Group on the Safety of Advanced Reactors. In 2021, the working group published a technical report titled "Regulatory Perspectives on Safety Aspects Related to Advanced Sodium Fast Reactors Part 4. Fuel Qualification for Sodium Fast Reactors".

- The NRC chairs the NEA's Loss of Forced Coolant Joint Project, an international experimental program designed to study important accident scenarios in high

temperature gas cooled reactors. With the NRC staff's leadership, the project was restarted in 2021 after being shut down for several years to perform Fukushima related upgrades to the facility.

In addition, the NRC continues to engage with developers through flexible and multi-staged non-LWR regulatory review processes for pre-application interactions. Based on indications from prospective applicants, the NRC staff expects pre-application engagement to increase in Calendar Year (CY) 2022.

Figure 2 shows some of the designs currently in development. It does not cover technologies such as fusion energy and accelerator-driven systems, and even within the listed categories of micro-reactors, liquid-metal-cooled fast reactors, HTGRs, and molten salt reactors (MSRs), it may not include all companies actively developing designs.

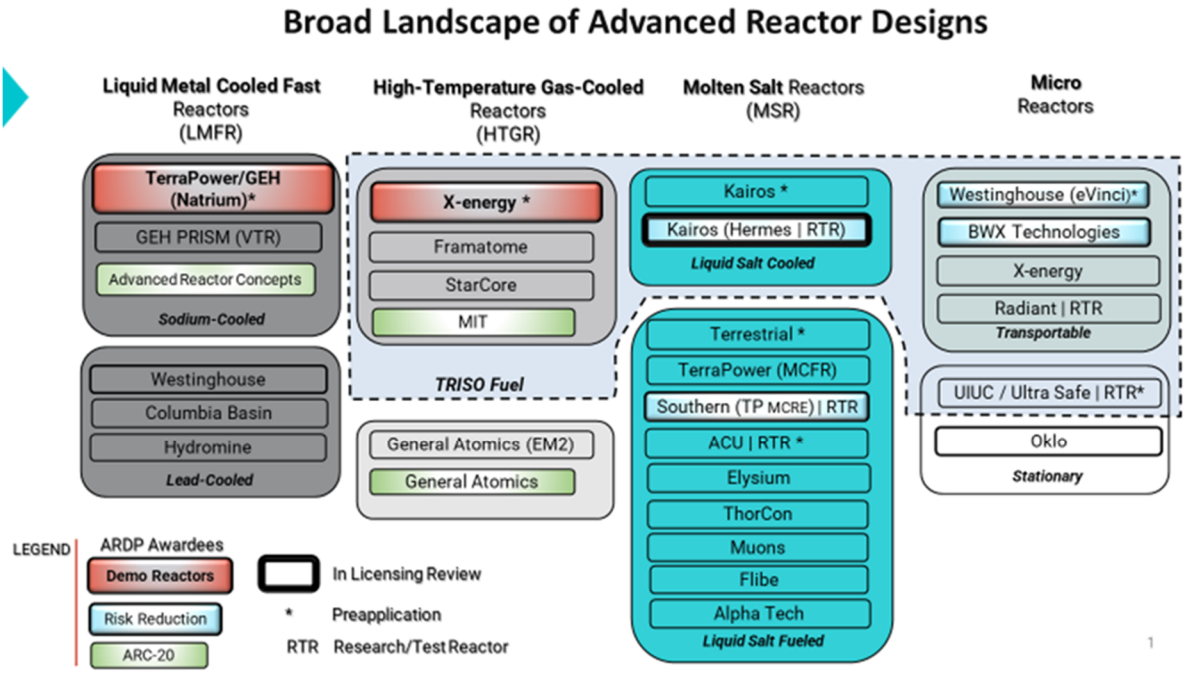

Figure 2 Companies developing non-LWR designs

2.0 Strategic Area No. 1: Staff Development and Knowledge Management

2.1 Overview

This strategic area supports the objective of enhancing non-LWR technical readiness. By investing in its people, the NRC can position itself to address the challenges of licensing new technologies. The near-term objectives in this area are to identify work requirements, identify critical skills and staff capacity requirements, assess the NRC staff's current non-LWR technical readiness, and close gaps in technical readiness. Activities within Strategic Area No. 1 are informed by ongoing U.S. Department of Energy (DOE) and industry technology development. The NRC also monitors the plans of prospective applicants to assess future workload and prioritize its readiness in technology-specific areas.

In 2021, the NRC successfully increased staff knowledge of non-LWRs, as described below. The NRC staff's main objective in Strategic Area No. 1 is to continue to expand its capabilities so that it is prepared to review the advanced reactor applications expected in the next few years.

2.2 Progress Summary

The NRC staff has enhanced its advanced reactor technical readiness in accordance with Section 103(a)(5) of NEIMA. This section requires the NRC to provide for staff training or hiring of experts to support the activities specified in Section 103(a)(1)–(4) of NEIMA, as well as to support preparations for pre-application interactions and license application reviews for commercial advanced reactors.

The inclusion of advanced reactor licensing in the same division as non-power production and utilization facility licensing allows the NRC staff to leverage synergies and experience in the licensing of novel technologies; for example, by using experience gained from the initial licensing of medical radioisotope facilities. Further, to prepare for potential early mover advanced reactor applications, the NRC reassigned subject matter experts from critical disciplines to the Division of Advanced Reactors and Non-power Production and Utilization Facilities (DANU), forming a core review team for conducting pre-application reviews; began the review of the Kairos Power construction permit application for a 35-megawatt thermal test reactor; and continued to develop the regulatory infrastructure for non-LWRs. During 2021, the NRC staff used strategic workforce planning to identify and fill vacancies in DANU to increase organizational capacity for the projected advanced reactor workload, including preparations for the Kairos Power construction permit application. During 2021, the NRC staff also continued to engage with Oklo Power LLC to obtain detailed technical information about the safety of the design that was missing from the combined license application; without this information, the NRC staff was unable to establish a schedule for the detailed technical review or reach safety findings required for licensing the facility. On January 6, 2022, the NRC denied, without prejudice, the Oklo COL application, based on Oklo's failure to provide information on several key topics for the Aurora design.[5]

In 2021,[6] the NRC staff focused on two types of activity in support of Strategic Area No. 1: (1) training and (2) knowledge management.

2.2.1 Training

In 2021, the NRC staff undertook training on many technical topics related to advanced reactor technologies.

The NRC staff participated in seminars on graphite degradation, aging, and failure mechanisms relevant to advanced non-LWR. The NRC staff, together with Sandia National Laboratories and ORNL, held workshops on using the NRC's SCALE and MELCOR codes to develop source terms for heat pipe reactors, HTGRs, and molten-salt-cooled PBRs.

The NRC staff also sponsored a seminar on light-water reactor (LWR) accident tolerant fuel (ATF), HALEU, and non-LWR fuel concepts, and their anticipated effects on the licensing of fuel

[5] See ADAMS Accession No. ML21357A034.

[6] This enclosure covers accomplishments through December 31, 2021, and discusses work currently planned for the remainder of FY 2022 with available budgeted resources.

cycle facilities, transportation packages, and spent fuel storage systems. Experts from ORNL and Sandia National Laboratories, as well as NRC staff, presented in the seminar, which covered major ATF technologies including doped uranium dioxide pellets, coated zirconium cladding, and iron-chromium-aluminum cladding, as well as higher initial enrichment fuel and higher discharge fuel burnup. It also covered advanced reactor technologies including reactors using tristructural isotropic (TRISO)-coated fuel particles (HTGRs and fluoride-salt-cooled high-temperature reactors (FHRs)); reactors using metallic uranium fuel (sodium-cooled fast reactors (SFRs) and heat pipe reactors); MSRs; and transportable reactors.

The NRC staff also attended the conferences, workshops, and meetings listed in Section 7.2.4, which provided other training opportunities.

Recorded training is available in the NRC's Talent Management System on MSRs, SFRs, micro-reactors, and HTGRs, for staff members new to advanced reactors that are involved in the licensing review of those designs. This training has been incorporated in reviewer qualification program requirements. Background reference material is also available, such as the report "NRC Regulatory History of Non-light Water Reactors (1950–2019)," dated June 10, 2019,[7] which introduces relevant concepts and historical context to staff members unfamiliar with non-LWRs.

Next steps: The NRC staff will continue to assess training needs and develop courses and other training opportunities, such as seminars on specific technical topics relevant to non-LWR technology.

2.2.2 Knowledge Management

Extensive information is available on technical, policy, and regulatory issues associated with licensing non-LWR designs. Knowledge management activities aim to consolidate existing materials to make them more easily accessible and searchable, and to develop additional resources as needed to support staff development.

This year, the NRC staff has continued to reorganize and regularly update the NRC's public Web site on advanced reactors,[8] to improve developers' and stakeholders' access to information and to increase both public and internal transparency. The Web site provides up-to-date information on public meetings, links to ARCAP draft guidance and to recently issued documents, the Advanced Reactor Summary of Integrated Schedule and Regulatory Activities, information on ongoing licensing activities and pre-application activities with specific vendors, and reports prepared for the NRC by the national laboratories.

The NRC staff has also developed and published several pages on advanced reactors and the non-LWR regulatory framework in the NRC's Nuclepedia knowledge management platform.[9] These include a main page that serves as a portal to more detailed information on advanced reactors; key training resources; and pages for specific non-LWR technologies, including SFRs, liquid-metal-cooled fast reactors, MSRs, micro-reactors, and fusion reactors.

The NRC staff is using DANU's SharePoint and Nuclepedia knowledge management platforms as the primary tools for knowledge management and to provide program status and information

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7 See ADAMS Accession No. ML19282B504.

8 See https://www.nrc.gov/reactors/new-reactors/advanced.html.

9 See https://nuclepedia.usalearning.gov/index.php?title=Advanced_Reactors.

in key focus areas. In 2021, the NRC staff developed several internal dashboard tools to enhance platform availability and use. In addition to updating the public Web pages, SharePoint, and Nuclepedia, the NRC staff conducted Executive Team Significant Topics briefings on topics such as advanced reactor program status, licensing activities, and specific non-LWR technologies. These briefings are typically widely attended by the NRC staff, and several were recorded for knowledge management purposes.

Next steps: In 2022, the NRC staff will continue to update the SharePoint and public Web sites and add non-LWR information to Nuclepedia to make the information more accessible within the agency.

3.0 Strategic Area No. 2: Analytical Tools

3.1 Overview

This strategic area supports the objective of enhancing non-LWR technical and regulatory readiness. The main goal in this strategic area is to develop the computer code capability needed for the NRC staff to perform independent analysis of advanced reactor designs. The NRC uses computer codes and tools to perform confirmatory, sensitivity, and uncertainty analyses to investigate design margins, commensurate with the risk and safety significance of the phenomena applicable to each specific design.

The NRC's approach in Strategic Area No. 2 is to (1) identify the tools, information, and data that the NRC staff may need in reviewing non-LWR designs, (2) evaluate the existing computer codes, tools, and supporting information to identify gaps in both analytical capabilities and supporting information and data, and (3) identify opportunities to collaborate with both domestic and international organizations working on non-LWR technologies, in order to close the gaps while avoiding conflicts of interest. Through these activities, the NRC staff will also develop technical bases to resolve major materials-related issues, such as those related to chemistry, component integrity, and seismic safety.

The NRC staff is continuing interactions related to computer codes and analytical tools with the DOE, the Electric Power Research Institute (EPRI), the national laboratories, reactor vendors, prospective licensees, and the international community. The NRC staff has built a cooperative relationship with the DOE, consistent with the NRC's statutory authority, to coordinate funding activities and reduce costs to the NRC and the U.S. Government.

3.2 Progress Summary

In 2021, the NRC staff developed further knowledge, technical skills, and capacity to strengthen the technical bases for regulatory decisions while increasing review agility. The NRC staff continued its efforts to identify the information, experimental data, and analytical tools needed to support non-LWR reviews. It also completed its assessment of existing computer codes and tools available for non-LWR reviews and other regulatory applications. The assessment included overall life-cycle costs and development schedules; it considered NRC-developed codes, codes developed by the DOE under the Nuclear Energy Advanced Modeling and Simulation project, and international codes. The NRC staff expects the codes identified for non-LWR analysis to be suitable for a broad range of postulated accidents and to accommodate reviews using either the LMP or more traditional licensing approaches. As part of its

assessment of analytical tools, the NRC staff has also identified knowledge and capability gaps and the code development tasks needed to close these gaps.

In addition, the NRC staff has identified and is assessing performance needs and issues related to seismic safety, materials, chemistry, and component integrity in non-LWR designs. Through strong engagement with domestic and international partners, the NRC staff has collected information on non-LWR operating experience and is heavily involved in activities related to consensus standards and codes. For example, the NRC staff has access to HTGR data from the Japanese High Temperature Engineering Test Reactor and to natural circulation data from integral test facilities, which could improve the agency's confirmatory analysis capability. For additional details on non-LWR cooperation with international partners see Section 7.2.5.

To improve its understanding of the unique codes, experimental data, features, phenomena, and knowledge gaps relevant to non-LWR technologies, the NRC staff has performed the following activities:

- The NRC staff participated in the development of the Phenomena Identification and Ranking Table (PIRT) for ORNL/TM-2021/2176, "Molten Salt Reactor Fundamental Safety PIRT" and the BN-114869-2018-IR, "Phenomena Important in Modeling and Simulation of Molten Salt Reactors"

- The NRC staff completed a series of reports documenting a comprehensive plan for developing computer code capabilities to support non-LWR reviews. This plan describes the overall code development approach, the codes themselves, knowledge gaps, and necessary development activities. These reports are available to the public and cover the follow topics:
  - The introduction gives an overview of the NRC's approach to code development in support of advanced reactor reviews.[10]
  - Volume 1 focuses on computer code readiness for plant systems analysis.[11]
  - Volume 2 focuses on computer code readiness for fuel performance analysis.[12]
  - Volume 3 focuses on computer code readiness for severe accident progression, source term, and accident consequence analysis.[13]
  - Volume 4 focuses on computer code readiness for licensing and siting dose assessments.[14]

[10] See "Approach for Code Development in Support of NRC's Regulatory Oversight of Non-light Water Reactors," dated January 31, 2020 (ADAMS Accession No. ML20030A174).

[11] See "NRC Non-light Water Reactor (Non-LWR) Vision and Strategy, Volume 1—Computer Code Suite for Non-LWR Plant Systems Analysis," dated January 31, 2020 (ADAMS Accession No. ML20030A176).

[12] See "NRC Non-light Water Reactor (Non-LWR) Vision and Strategy, Volume 2—Fuel Performance Analysis for Non-LWRs," dated January 31, 2020 (ADAMS Accession No. ML20030A177).

[13] See "NRC Non-light Water Reactor (Non-LWR) Vision and Strategy, Volume 3—Computer Code Development Plans for Severe Accident Progression, Source Term, and Consequence Analysis," dated January 31, 2020 (ADAMS Accession No. ML20030A178).

[14] See "NRC Non-light Water Reactor (Non-LWR) Vision and Strategy, Volume 4—Licensing and Siting Dose Assessment Codes," issued August 2020 (ADAMS Accession No. ML20028F255).

  - Volume 5 focuses on computer code readiness for criticality and shielding considerations for the front and back end of the fuel cycle.[15]

- To prepare to perform independent advanced reactor safety analyses using the capabilities covered in Volumes 1, 2, and 3 of the plan, the NRC staff is developing reference plant models from publicly available information. The purpose of this effort is to test the codes and models and identify and correct errors ahead of future licensing support.

- Under Volume 1, the NRC staff has developed initial models from publicly available information for designs such as heat pipe, sodium-cooled fast, and pebble bed fluoride-salt-cooled high-temperature reactors. These models will be revised as applicant design information becomes available. The models help to build staff and contractor expertise in the use of computer codes, analytical modeling, and the design and operation of the different types of advanced reactors. The NRC staff is currently developing reference plant models for a molten-salt-fueled thermal reactor and gas-cooled pebble bed reactor. Under an addendum to the Nuclear Energy Innovation Capabilities Act of 2017 (NEICA), highlighted in Section 7 of this enclosure, the NRC also has access to analytical models and codes being developed under the DOE's Virtual Test Bed program, which will complement the NRC's Volume 1 models and support the agency's readiness for advanced reactors.

- Using capabilities developed under Volume 2, the NRC staff completed an evaluation of metallic and TRISO fuel models and identified potential improvements for the Fuel Analysis under Steady-state and Transients (FAST) fuel performance computer code. The NRC staff added material property correlations, spherical solvers, and TRISO mechanical failure modes to FAST. The NRC staff is collaborating with Idaho National Laboratory (INL) to assess FAST and Bison against Experimental Breeder Reactor data.

- Under Volume 3, the NRC staff developed reference plant models from publicly available information for a heat pipe reactor, an HTGR, and a molten-salt-cooled PBR. The NRC staff applied these models to a range of accident scenarios to demonstrate code capability and to provide a first look at non-LWR accident progression. The NRC staff used the results of this work to hold staff training workshops, as well as public workshops to facilitate dialogue on the NRC's approach for non-LWR source terms. The NRC staff now is developing reference plant models for a molten-salt-fueled reactor and an SFR, on which it will also hold public workshops.

- Using capabilities developed under Volume 3, the NRC staff completed near-field atmospheric transport and dispersion model improvements in the MELCOR Accident Consequences Code System (MACCS) consequence analysis code. The NRC staff also completed the MACCS radionuclide screening analysis for several non-LWR technologies. The NRC staff is currently updating MACCS to incorporate near-field atmospheric transport and dispersion and dose calculation improvements.

- In the areas of licensing and siting dose assessment computer codes described in Volume 4, Pacific Northwest National Laboratory (PNNL) completed the report

[15] See "NRC Non-light Water Reactor (Non-LWR) Vision and Strategy, Volume 5—Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle," dated November 3, 2020 (ADAMS Accession No. ML20308A744).

PNNL-30355, “DRAFT Software Requirements Document for an Atmospheric Dispersion Engine.” The NRC staff reviewed and provided comments for disposition of the final report. PNNL is developing an atmospheric dispersion engine from the consolidated calculation algorithms of the ARCON, PAVAN, and XOQDOQ Fortran codes; it expects to release the prototype in 2022.

Next steps: The NRC staff continues to assess the information, experimental data, and analytical tools needed to support non-LWR reviews. The NRC plans to continue developing its own codes, while leveraging DOE codes to fill any gaps. The NRC staff will focus on technology-inclusive capabilities and on enhancing its understanding of, and regulatory readiness to review, the materials likely to be proposed for use in advanced reactors, which include high-temperature alloys, graphite, and molten salt.

The NRC staff will continue to develop proof-of-concept reference plant models for plant systems analysis and for accident progression and source term analysis; it expects to complete four more models in the next year beyond the six models already completed in 2021. For fuel performance, the NRC staff will continue to address gaps identified in the assessment reports. For consequence analysis, the NRC staff plans to update radionuclide properties, atmospheric transport, and dosimetry over the next year. For licensing and siting dose assessment computer codes, the next step is to complete the consolidated atmospheric dispersion engine code. The NRC staff will continue scenario selection for demonstrating code capabilities related to criticality and shielding for the front and back end of the fuel cycle. The NRC staff is also conducting a preliminary assessment of technical information needs and regulatory considerations for future MSR fuel cycles, including activities related to the fabrication and transportation of fuel-salt mixtures.

4.0 Strategic Area No. 3: Regulatory Framework

4.1 Overview

This strategic area supports the objective of optimizing non-LWR regulatory readiness. One of the NRC’s goals in Strategic Area No. 3 is to develop guidance for flexible non-LWR regulatory review processes, including conceptual design reviews and staged review processes, within the bounds of existing regulations. In 2021, the NRC staff reprioritized activities to support the development of technology-inclusive, RIPB licensing approaches that require new regulations, in support of the NRC’s goal of being a modern, risk-informed regulator.

4.2 Progress Summary

4.2.1 Non-light-Water Reactor Licensing-Basis Development

In 2021 the NRC staff continued to work with stakeholders to create guidance for non-LWR developers on the content of applications that use the LMP methodology. The industry finalized the LMP methodology in the Nuclear Energy Institute (NEI) report NEI 18-04, Revision 1, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-light Water Reactor Licensing Basis Development,” issued August 2019. The Commission approved the use of the LMP methodology in Staff Requirements Memorandum (SRM)-SECY-19-0117, “Staff Requirements—SECY-19-0117—Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses,

Certifications, and Approvals for Non-light-Water Reactors," dated May 26, 2020.[16] Following the Commission's approval, the NRC staff endorsed NEI 18-04 in RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-light-Water Reactors," issued June 2020. The NRC staff subsequently prepared the Part 53 rulemaking plan (SECY-20-0032, "Rulemaking Plan on 'Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062),"[17] and noted the NRC staff's intent to build upon the LMP approach to develop the rule. The LMP methodology focuses on key areas of the design and licensing of advanced reactors, such as the selection of licensing-basis events; classification of structures, systems, and components; and assessment of defense in depth.

Under TICAP, the NRC staff plans to cover the scope and level of detail for the safety analysis report portion of an application based on the LMP methodology. The NRC staff recognizes that some portions of an application, such as occupational dose and routine plant radiological effluents, are outside the scope of TICAP and the LMP methodology. Therefore, the NRC staff is also working with stakeholders on ARCAP, which encompasses TICAP and includes guidance for portions of applications not covered by TICAP.

In 2021, the NRC staff conducted eight public meetings to discuss the draft TICAP and ARCAP guidance with stakeholders. In addition, the NRC staff participated in four tabletop exercises with the industry to demonstrate the use of the TICAP draft guidance to develop portions of the license applications for various advanced reactor designs. The tabletop exercise results appear in the publicly available reports for the Westinghouse Electric Company eVinci microreactor,[18] the TerraPower Molten Chloride Reactor Experiment,[19] the X-energy Xe-100 HTGR,[20] and the VTR sodium-cooled metallic-fueled pool-type fast reactor.[21]

As a result of these interactions, on August 30, 2021, the industry issued NEI 21-07, Revision 0, "Technology Inclusive Guidance for Non-light Water Reactors: Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology."[22] The NRC staff is currently updating a draft TICAP guidance document,[23] which has been discussed with stakeholders in a series of public meetings and is intended to endorse NEI 21-07, Revision 0, with appropriate exceptions, clarifications, and additions.

The NRC staff also continued its efforts under ARCAP to develop guidance for portions of the application outside the scope of TICAP. In 2021, the NRC staff issued the following ARCAP preliminary documents to support the development of interim staff guidance:

- "Guidance for Performing the Review of a Technology-Inclusive Advanced Reactor Application—Review Roadmap"[24]

16 See ADAMS Accession No. ML20147A504.
17 See ADAMS Accession No. ML19340A047.
18 See ADAMS Accession No. ML21272A303.
19 See ADAMS Accession No. ML21228A222.
20 See ADAMS Accession No. ML21217A086.
21 See ADAMS Accession No. ML21272A338.
22 See ADAMS Accession No. ML21250A378.
23 See ADAMS Accession No. ML21190A014.
24 See ADAMS Accession No. ML21190A012.

- "Advanced Reactor Content of Application Chapter 2 'Site Information'"[25]
- "Advanced Reactor Content of Application Chapter 9 'Control of Routine Plant Radioactive Effluents, Plant Contamination and Solid Waste'"[26]
- "Advanced Reactor Content of Application Chapter 10 'Control of Occupational Dose'"[27]
- "Advanced Reactor Content of Application 'Organization and Human-System Considerations'"[28]
- "Advanced Reactor Content of Application Chapter 12 'Post-construction Inspection, Testing, and Analysis Program'"[29]
- "Advanced Reactor Content of Application 'Risk-Informed, Performance-Based Fire Protection Program (for Operations)'"[30]
- "Advanced Reactor Content of Application 'Risk-Informed ISI/IST Programs'"[31]
- "Advanced Reactor Content of Application 'Risk-Informed Technical Specifications'"[32]

In addition, during 2021, the NRC staff began developing a framework document for the construction inspection and oversight program (ARCOP), with support from both internal NRC staff and external experts in construction inspection and oversight for power reactors and research and test reactors. As part of this effort, the NRC staff examined lessons learned from recent NRC construction inspection and oversight experiences for new reactors (e.g., Vogtle Electric Generating Plant, Units 3 and 4), new non-power production and utilization facilities (e.g., the SHINE Technologies, LLC, Medical Isotope Production Facility), and recent operating experience with research and test reactors (e.g., that of the National Institute of Standards and Technology). The ARCOP development effort will consider a broad range of advanced non-LWR designs and technologies, including micro-reactors, as well as light-water SMRs. It will also consider the full spectrum of construction, fabrication, and manufacturing environments, from completely factory-built reactors with minimal site preparation to larger reactors involving site preparation and onsite construction activities resembling current practice. It will incorporate insights from advanced manufacturing techniques and remote inspection and monitoring methods introduced recently in the nuclear industry, as well as those used in other industries with similar risk profiles. The NRC staff engaged advanced reactor stakeholders to discuss its initial vision for the ARCOP framework during a public meeting in 2021; it will conduct more external outreach in fiscal year (FY) 2022.

Next steps: The NRC staff plans to complete a draft ARCOP framework in FY 2022. The NRC staff will continue to develop ARCAP and TICAP guidance, engaging extensively with stakeholders to obtain further input. These activities contribute significantly to (1) the NRC's goal of increasing its use of RIPB licensing evaluation techniques and guidance and (2) the

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25 See ADAMS Accession No. ML21189A031.
26 See ADAMS Accession No. ML21189A033.
27 See ADAMS Accession No. ML21189A035.
28 See ADAMS Accession No. ML21309A020.
29 See ADAMS Accession No. ML21294A266.
30 See ADAMS Accession No. ML21253A134.
31 See ADAMS Accession No. ML21216A051.
32 See ADAMS Accession No. ML21133A490.

NRC's rulemaking to establish a technology-inclusive regulatory framework for advanced reactors, as required by NEIMA.

4.2.2 Fuel Qualification Strategies

The considerable experience base for traditional LWR fuel may not apply to proposed advanced reactor technologies, which use different fuel designs and operating environments (e.g., neutron energy spectra, fuel temperatures, neighboring materials). Advanced reactor designers are considering several fuel types, including fuels based on TRISO particles, metallic uranium alloys, and liquid salt fuels. The NRC staff is consulting with the DOE and the national laboratories on the qualification of each of these fuel types. The NRC staff is also discussing fuel qualification with individual developers and other stakeholders.

The type of fuel affects many aspects of the overall design of a nuclear power plant, and fuel qualification has historically required long development times. Recognizing these challenges, in early 2020 the NRC staff began developing guidance on a performance-based fuel qualification assessment framework for advanced reactor technologies, including both power and non-power reactors. This framework follows a top-down approach in which lower-level objective goals support high-level regulatory requirements. In September 2020, the NRC staff issued a draft white paper[33] describing the bases for the identified goals, with clarifying examples of the evidence needed to meet the goals. The NRC staff discussed the draft white paper with stakeholders in a public meeting on October 1, 2020, and with the ACRS Future Plant Designs Subcommittee in February 2021. Incorporating feedback from the ACRS and stakeholders, including the industry-led Accelerated Fuel Qualification Working Group, the NRC staff converted the draft white paper into draft NUREG-2246, which it issued for public comment in June 2021. The NRC staff responded to public comments and discussed the draft NUREG with the ACRS Full Committee on November 3, 2021. The ACRS concluded that the NUREG provides a logical approach to fuel qualification that includes identifying relevant experimental data and assessing associated safety margin. The NRC staff plans to issue the final NUREG-2246 in February 2022. The framework in NUREG-2246 is being exercised for a generic assessment of metal fuel through a contract with INL and for TRISO fuel through a contract with PNNL.

With ORNL support, the NRC staff is developing fuel qualification criteria for liquid-fueled MSRs. As part of this effort, ORNL prepared ORNL/LTR-2018/1045, "Molten Salt Reactor Fuel Qualification Considerations and Challenges," issued November 2018,[34] and ORNL/TM-2020/1576, "MSR Fuel Salt Qualification Methodology," issued July 2020.[35] The NRC has contracted with ORNL to develop a draft NUREG/CR[36] for the fuel qualification of liquid-fueled MSRs. The NRC staff discussed the draft NUREG/CR with the ACRS Full Committee on November 3, 2021, and with advanced reactor stakeholders in a public meeting on November 10, 2021. The ACRS concluded that the NUREG/CR provides a reasonable and practical approach to developing a licensing basis for fuel qualification for MSRs.[37]

The NRC is also working with stakeholders, including the DOE, to identify and resolve potential technical issues with the planned use of HALEU in some advanced reactor designs, including

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33 See "Fuel Qualification for Advanced Reactors (Draft)" (ADAMS Accession No. ML20191A259).
34 See ADAMS Accession No. ML18347A303.
35 See ADAMS Accession No. ML20197A257.
36 See ADAMS Accession No. ML21245A493.
37 See ADAMS Accession No. ML21313A361.

any needed licensing of fuel cycle facilities and transportation packages. In June 2021, the NRC staff approved Centrus Energy Corporation's license amendment request to produce HALEU at its Piketon, OH, fuel enrichment facility.[38]

To ensure alignment with the 10 CFR Part 53 rulemaking,[39] discussed under Section 6.2 below, the NRC staff plans to evaluate applicability to advanced reactors of the regulatory basis for rulemaking to amend 10 CFR 50.68, "Criticality accident requirements," for the use of LWR fuel containing uranium enriched to greater than 5.0 weight percent uranium-235. The NRC staff notes that, if the rulemaking schedule and stakeholder interest align, the NRC could expand the scope of the rulemaking or could initiate a separate rulemaking for advanced reactor fuel designs.

In response to Commission direction in SRM-SECY-19-0095, "Staff Requirements—SECY-19-0095—Discontinuation of Rulemaking—Enhanced Security of Special Nuclear Material," dated August 4, 2021, the NRC staff is developing a notation paper presenting a full range of options for the scope of the rule on enhanced security of special nuclear material, together with the potential regulatory, resource, and timing impact of each option.

Advanced reactor developers have already begun to submit design specific topical reports to the NRC for review and approval of their fuel qualification plans, and more are expected. During 2021, the NRC staff continued generically applicable fuel qualification activities while also engaging with advanced reactor developers on specific fuel qualification issues. For example, the NRC staff is currently reviewing topical reports from Kairos Power and X-energy on design specific fuel qualification, and it has provided feedback[40] on the TerraPower white paper, "Advanced Fuel Qualification Methodology Report—Regulatory Guidance Development Report," dated July 16, 2020, and the General Atomics white paper, "Energy Multiplier Module (EM2) Accelerated Fuel Qualification Strategy," dated June 8, 2021. To support staged licensing approaches, the NRC staff encourages early engagement and feedback from developers on technical issues.

Next steps: The NRC staff plans to issue the final NUREG-2246 in February 2022. The framework in NUREG-2246 is being exercised for a generic assessment of metal fuel through a contract with INL and for TRISO fuel through a contract with PNNL. The NRC staff plans to issue the options paper for the scope of the rule on enhanced security of special nuclear material.

4.2.3 Additional Guidance Development Activities

In addition to the specific activities discussed in Section 4.2.1, the NRC staff identified two broad regulatory framework development activities in support of Strategic Area No. 3:

(1) Establish criteria, as necessary, to reach safety, security, and environmental findings for non-LWR technologies.

(2) Identify and resolve gaps in the current regulatory framework for non-LWRs and the relevant fuel cycles.

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38 See ADAMS Accession No. ML21138A827.
39 See ADAMS Accession No. ML19340A056.
40 See ADAMS Accession No. ML20310A278.

The following specific activities support these two broad activities:

- On September 24, 2021, the NRC staff issued for public comment draft NUREG-2159, Revision 1, Acceptable Standard Format and Content for the Fundamental Nuclear Material Control Plan Required for Special Nuclear Material of Moderate Strategic Significance.[41]. The public comment period was closed on December 3, 2021. The NRC staff is working on resolving public comments and plan to publish the final version of NUREG-2159, Revision 1, in March 2022.

- On September 21, 2020, in SRM-SECY-20-0020, "Staff Requirements—SECY-20-0020—Results of Exploratory Process for Developing a Generic Environmental Impact Statement for the Construction and Operation of Advanced Nuclear Reactors," the Commission directed the NRC staff to initiate rulemaking to codify the advanced nuclear reactor GEIS. The NRC staff drafted the GEIS and the associated proposed rule package in 2021 and submitted them on November 29, 2021, for Commission review and approval. If the Commission approves them, the NRC staff will release the draft GEIS and proposed rule for public comment.

- To modernize the instrumentation and controls safety review of non-LWR applications, the NRC staff drafted "Design Review Guide (DRG): Instrumentation and Controls for Non-Light-Water Reactor (Non-LWR) Reviews," revised February 26, 2021.[42] This guide assists the NRC staff in reviewing the instrumentation and controls portions of applications for non-LWRs within the bounds of existing regulations. It leverages the framework of the NuScale Design-Specific Review Standard, Chapter 7, while factoring in the lessons learned from new reactor reviews.

- The NRC staff anticipated the need to conduct HFE reviews of applications for facilities (e.g., small and micro non-LWRs) that differ substantially from the large LWRs for which the NRC developed NUREG-0711, "Human Factors Engineering Program Review Model," issued November 2012. For such facilities, a scalable or graded process is needed to (1) assess the potential contribution of human performance to the risk that the facility presents to public health and safety and (2) assess, commensurate with that risk, whether the facility design or design process is adequate to identify and address this contribution. The NRC staff contracted with Brookhaven National Laboratory to develop an HFE process and guidance for non-design-specific technical reviews of small, advanced reactors. The resulting five-step process is sensitive to the NRC's new vision for advanced reactor reviews, including the requirements in NEIMA. In the new approach, existing NRC review processes and criteria do not structure the review process. Instead, they serve as resources that the reviewer can use when appropriate. A Brookhaven National Laboratory technical letter report[43] documents the process. The NRC staff intends to use the BNL TLR as the basis for NRC staff guidance and plans to turn the report into an ISG document that will take the BNL process and facilitate its application by the NRC staff in conducting scalable human factors engineering reviews for advanced reactor applications.

- The NRC staff contracted with INL to develop guidance on operator licensing examinations for advanced reactors. The guidance will (1) outline an acceptable process for applicants to develop both initial and continuing examination methods that

41 See ADAMS Accession No. ML21263A119.
42 See ADAMS Accession No. ML21011A140.
43 See ADAMS Accession No. ML21287A088.

can be tailored to different types of advanced reactor facilities and (2) define review criteria by which the NRC staff can establish that an applicant's proposed approach to operator licensing will provide reasonable assurance of safe operation of the facility. INL is currently reviewing existing guidance, state-of-the-art research on educational testing, and benchmarking licensing and credentialing practices in other safety-critical industries. The INL will document its guidance in a draft white paper that it plans to submit to the NRC in April 2022. The NRC will release a final draft of the white paper for public comment at the end of the study.

Next steps: In 2022, the NRC staff will continue to develop fuel qualification guidance for advanced reactors, ARCAP and TICAP regulatory guidance, HFE guidance, a framework document for advanced reactor inspection and oversight, and MC&A guidance for Category II facilities (NUREG-2159, Revision 1).

5.0 Strategic Area No. 4: Consensus Codes and Standards

5.1 Overview

This strategic area supports the objective of enhancing non-LWR technical and regulatory readiness. The NRC staff intends to apply its established process for incorporating codes and standards into its regulatory framework. NRC Management Directive 6.5, "NRC Participation in the Development and Use of Consensus Standards," dated October 28, 2016, describes this process, which has three steps: (1) identifying and prioritizing needs for new and revised technical standards, (2) participating in the development of codes and standards, and (3) endorsing codes and standards. The NRC is working with standards development organizations (SDOs), non-LWR designers, the DOE, and other stakeholders to identify and facilitate new codes needed for non-LWR development.

5.2 Progress Summary

5.2.1 The American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 5, for High-Temperature Reactors

The ASME BPVC provides NRC-accepted rules for the design, construction, testing, certification, and quality assurance of nuclear reactors with systems operating below 425 degrees Celsius (800 degrees Fahrenheit). However, non-LWR designs may incorporate novel materials or systems operating above 425 degrees Celsius. At these elevated temperatures, the structural capacity of systems and components will change as a function of time, temperature, and previously applied stress. BPVC-III-5 provides rules for the design, construction, testing, certification, and quality assurance of high-temperature reactors; it covers the use of metallic, graphite, and composite materials. ASME and the industry technology working groups for the major advanced reactor types (i.e., HTGRs, MSRs, and fast reactors) have requested that the NRC endorse the 2017 Edition of the ASME BPVC to improve the efficiency and effectiveness of the agency's review process, to provide non-LWR designers a stable set of rules for reactor development, and to facilitate the certification of non-LWR component vendors.

The NRC staff working with its contractors continued to update codes and software tools to strengthen technical bases for non-LWR regulatory decisions, for example, with the following work:

- Argonne National Laboratory (ANL) completed the report ANL-21/25, "Assessing the ASME Section III, Division 5, Class A Primary Load Design Rules against Creep Notch Effects," which assesses how well the current ASME code rules for high-temperature reactors deal with the effects of complex, multiaxial stresses on creep fatigue. The report follows work completed in 2020 on environmental creep fatigue. The NRC staff is considering enhancements to a software tool completed in 2020 that executes the design rules of the ASME BPVC, Section III, "Rules for Construction of Nuclear Facility Components," Division 5, "High Temperature Reactors" (BPVC-III-5); the NRC may distribute this tool to stakeholders through its public Web site.

- The NRC staff is continuing to work with the Southwest Research Institute, to develop a technology-inclusive, RIPB pathway for advanced non-LWRs to address seismic safety within the LMP framework. One part of the contract aims to (1) evaluate the feasibility and adequacy of potential technical criteria through demonstration studies; (2) perform communication and outreach activities to help reach consensus with pertinent stakeholders on a viable and practical technology-inclusive, RIPB approach for advanced non-LWR seismic safety; (3) develop associated implementation guidance; and (4) identify potential regulatory improvements for future rulemaking activities. The other part of the contract aims to identify and evaluate technical criteria for regulatory guidance on the design and review of seismic isolation technologies included in commercial nuclear power plant licensing applications.

- The NRC staff issued TLR-RES/DE/CIB-CMB/2021-05, which describes ongoing research targeting near-term goals and strategies and discusses potential future activities that would build on current efforts and results and support longer-term plans. The planned activities focus on technology-specific and materials-specific topics, including MSR technology and material behavior, advanced manufacturing and qualification of high-temperature alloys, storage for irradiated MSR byproducts, data analytics, advanced sensors, and online surveillance monitoring. They aim to leverage domestic and international partnerships to identify challenges and gaps related to advanced reactor regulation.

- Under contract with the NRC, ORNL is performing confirmatory testing and analysis of various corrosion measurement techniques. Under this contract, the effort has produced three reports: TLR-RES/DE/CIB-CMB-2021-07, "Corrosion in Sodium Fast Reactors," issued May 2021[44]; TLR-RES/DE/CIB-CMB-2021-03, "Technical Assessment of Materials Compatibility in Molten Salt Reactors," issued March 2021[45]; and TLR-RES/DE/CIB-CMB-2021-04, "Corrosion in Gas-Cooled Reactors," issued March 2021.[46] These reports will inform non-LWRs licensing reviews.

- Under contract with the NRC, INL is providing technical support related to the use of graphite in advanced non-LWRs. INL has conducted seminars with the NRC staff on graphite degradation, aging, and failure mechanisms relevant to advanced non-LWRs. The NRC staff is also engaged with INL to develop tools for modeling graphite behavior in advanced non-LWRs, as well as training the NRC staff in the use of these tools.

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44 See ADAMS Accession No. ML21116A231.
45 See ADAMS Accession No. ML21084A039.
46 See ADAMS Accession No. ML21084A041.

Next steps: The NRC staff plans to develop draft staff positions on RIPB seismic safety in the design of advanced reactors, as well as a draft technical document on the use of seismic isolators.

The NRC staff is actively participating in working groups and subgroups associated with the development of BPVC-III-5. NRC staff members representing the agency on the ASME Qualification of Active Mechanical Equipment (QME) Committee and BPVC-III-5 committees are also supporting the development of rules for active components operating above 425 degrees Celsius.

On July 20, 2021, the NRC staff briefed the ACRS Future Plant Designs Subcommittee on its BPVC-III-5 endorsement effort.[47] In August 2021, the NRC staff issued two draft documents for public comment:

(1) DG-1380, which will become RG 1.87, Revision 2, when final, and which provides the results of the NRC review and lists exceptions and limitations to be applied to the use of BPVC-III-5

(2) NUREG-2245, which documents the NRC staff's technical evaluation of BPVC-III-5 and the associated Code Cases N-861 and N-862, incorporating expert recommendations from DOE national laboratories and commercial entities as appropriate

The public comment period for these two documents closed on October 19, 2021.

The NRC staff is currently reviewing Code Cases N-872 and N-898, which permit the use of Alloy 617 with BPVC-III-5 for low-temperature service and elevated-temperature service, respectively. Alloy 617 will supplement the five materials currently allowed by BPVC-III-5 for use in high-temperature Class A components. Because Alloy 617 has better high-temperature strength than the currently allowed materials, it can be used to higher maximum temperatures, which may be important for some non-LWR designs. Code Cases N-872 and N-898, approved by ASME in 2020, represent the first new materials to be allowed for use with BPVC-III-5 since its initial publication in 2011.

The NRC staff has contracted with commercial entities to provide expert recommendations on endorsement of Code Cases N-872 and N-898. DG-1380 and NUREG-2245 will incorporate the results of the NRC staff's review.

Next steps: The NRC staff plans to issue a revision to DG-1380 and a supplement to NUREG-2245 that incorporates the Alloy 617 Code Cases for public comment (limited to the Alloy 617 portions) in spring 2022. Subsequently, the NRC staff will address public comments and engage with the ACRS to finalize DG-1380 (RG 1.87, Revision 2) and NUREG-2245, as well as their respective comment resolution documents. The NRC staff plans to issue the final NUREG-2245 and RG 1.87, Revision 2, in FY 2022. The NRC staff has updated stakeholders, and will continue to do so, in the ASME BPVC Week meetings, the NRC's Standards Forum, the advanced reactor stakeholder meetings, and other public venues.

5.2.2 The American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, Division 2 for Reliability and Integrity Management (RIM) Programs

[47] See meeting transcript at ADAMS Accession No. ML21257A324.

BPVC-XI-2 provides a process for developing a RIM program, similar to a traditional preservice and inservice inspection program under the ASME BPVC, Section XI, Division 1, "Rules for Inspection and Testing of Components of Light-Water-Cooled Plants" (BPVC-XI-1), for all types of nuclear power plants. The RIM program lets plant owners implement alternative strategies from BPVC-XI-1 to maintain the reliability of plant structures, systems, and components. It contains provisions beyond those of a traditional program; for example, it allows for significant use of PRA to develop reliability targets for structures, systems, and components. BPVC-XI-1 is incorporated by reference in 10 CFR 50.55a, but the NRC's regulations and guidance currently do not reference BPVC-XI-2. ASME has requested that the NRC endorse the 2019 Edition of BPVC-XI-2 in 10 CFR 50.55(a).

The NRC recognizes that non-LWR designers would benefit from a standardized set of requirements for design, construction, and inservice inspection. The NRC staff has reviewed BPVC-XI-2 for non-LWR applications and has endorsed it, with conditions, in DG-1383, which the agency issued for public comment on September 30, 2021.

Next steps: The NRC staff will address any public comments received on DG-1383 and expects to issue the final RG endorsing the 2019 Edition of BPVC-XI-2 in FY 2022. The NRC staff has updated stakeholders, and will continue to do so, at the ASME BPVC Week meetings, the NRC's Standards Forum, the advanced reactor stakeholder meetings, and other public venues.

5.2.3 American Nuclear Society Standards

The NRC participates in several ANS standards development working groups and consensus committees. The table below shows the status of each.

Standard/Committee	Status
Research and Advanced Reactor Consensus Committee (RARCC)	The last meeting took place in November 2021; the next meeting will occur in November 2022.
Risk-Informed, Performance-Based Principles and Policy Committee	No meetings scheduled at this time.
ANS 53.1, "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants"	Issued in 2011, reaffirmed in 2016 and again in 2021. ANS plans to update this standard. The RARCC is forming a working group. Significant modifications are needed to align the standard with RG 1.233.
ANS 54.1, "Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled Nuclear Power Plants"	Final standard issued March 27, 2020.
ANS 20.1, "Nuclear Safety Criteria and Design Process for Fluoride Salt-Cooled High-Temperature Reactor Nuclear Power Plants"	Project Initiation Notification System (PINS) form submitted to ANSI on February 26, 2014. The development of this standard is on hold because of limited applicability to industry.
ANS 20.2, "Nuclear Safety Design Criteria and Functional Performance Requirements for	PINS form submitted to ANSI on July 7, 2016. The working group held frequent meetings and

Standard/Committee	Status
Liquid-Fuel Molten-Salt Reactor Nuclear Power Plants”	conference calls in 2021. The standard was submitted for full committee balloting in December 2021.
ANS 30.1, “Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs” (proposed)	Proposed; PINS form submitted to ANSI on July 31, 2016. The working group has held frequent meetings and conference calls in 2021 to address industry stakeholder comments on the draft standard. In 2022, the working group will address the remaining issues and identify the best path forward.
ANS 30.2, “Categorization and Classification of Structures, Systems, and Components for New Nuclear Power Plants” (proposed)	Proposed; PINS form submitted to ANSI on July 7, 2016. The working group held frequent meetings and conference calls in 2021. The draft standard is under development.

Next steps: The NRC will continue to participate in ANS committees and standards development working groups, as appropriate, to support standards for non-LWR technologies.

5.2.4 Development of the American Society of Mechanical Engineers/American Nuclear Society Non-Light-Water Reactor Probabilistic Risk Assessment Standard

In 2013, the ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM) issued ASME/ANS RA-S-1.4-2013 for trial use. The technical requirements for this standard were developed using source material from the existing ASME/ANS Level 1 full-power LWR PRA standard—namely, ASME/ANS RA-Sa-2009, “Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications,” as revised in ASME/ANS RA-Sb-2013 (Addendum B)—as well as from draft LWR standards for low-power and shutdown PRA, Level 2 PRA, and Level 3 PRA.

To support a variety of reactor concepts, including HTGRs, SFRs, and MSRs, the JCNRM has updated ASME/ANS RA-S-1.4-2013 on a reactor-technology-inclusive basis, using established technology-inclusive risk metrics common to existing LWR Level 3 PRAs. Such risk metrics include frequency of radiological consequences (e.g., dose, health effects, and property damage). To cover the wide range of applications defined by non-LWR stakeholders, this standard has a very broad scope, comparable to that of a full-scope Level 3 PRA for an LWR with a full range of plant operating states, radiological sources, and hazards. Because the standard supports modular reactor concepts, it addresses the evaluation of integrated risk for multi-reactors or multiunit plants, including concurrent accidents on two or more reactor units or modules.

Several national and international organizations are using the standard as they develop non-LWR PRAs. These organizations provided valuable feedback to the JCNRM writing group for incorporation into the final draft of the standard. In September 2020, the JCNRM voted to approve the final draft. The updated ASME/ANS RA-S-1.4 was published in February 2021 as a consensus standard. NEI developed guidance for peer reviews for the non-LWR PRAs and

submitted NEI 20-09, “Performance of PRA Peer Reviews Using the ASME/ANS Advanced Non-LWR PRA Standard,” to the NRC in May 2021.

The NRC staff is reviewing ASME/ANS RA-S-1.4 and NEI 20-09 for endorsement. The NRC staff made the preliminary trial use RG (TRG 1.247)[48] publicly available in August 2021 and briefed the ACRS Future Plant Designs Subcommittee and the Full Committee on it in September 2021 and October 2021, respectively. The NRC staff received numerous comments from stakeholders including the JCNRM, NEI, and industry representatives, and is considering them in its development of the TRG.

Next steps: The NRC staff expects to issue TRG 1.247 in early 2022. Applicants may use this guidance on a trial basis. Before finalizing the RG, the NRC staff will incorporate lessons learned from these piloted applications of the guidance, as well as any revisions to ASME/ANS RA-S-1.4.

5.2.5 The Standards Forum

The NRC Standards Forum aims to do the following:

- Identify standards needed within the nuclear industry that SDOs are not currently addressing and explore collaborations to accelerate their development.
- Identify process improvements for effective and timely standards development.
- Exchange information on standards for nuclear facilities across disciplines and stakeholders.
- Facilitate engagement and networking within the standards development community.

On September 15, 2021, the NRC staff held the fifth annual NRC Standards Forum, chaired by the NRC’s Standards Executive. Approximately 190 attendees joined the event, including participants from the NRC; SDOs such as ANS, ASME, American Concrete Institute, American Society of Civil Engineers, and Institute of Electrical and Electronics Engineers; NEI; EPRI; DOE; DOE national laboratories, including INL and Savannah River National Laboratory; and academia. The NRC Web site offers a full summary and related documents.[49]

This year’s event included three sessions, which covered recent codes and standards initiatives across SDOs and within the NRC, recent developments related to codes and standards for new and advanced reactors, and ongoing activities supporting the development of standards for advanced manufacturing. The discussions highlighted areas for further collaboration across SDOs, as well as ways for the NRC and stakeholders to be more effective in developing, updating, and meeting the needed codes and standards.

Next steps: The NRC staff expects to hold the next NRC Standards Forum in fall 2022.

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48 See ADAMS Accession No. ML21246A216.

49 See https://www.nrc.gov/about-nrc/regulatory/standards-dev/standards-forum/2020.html.

6.0 Strategic Area No. 5: Resolution of Policy Issues

6.1 Overview

This strategic area supports the identification and resolution of policy issues within the purview of the NRC that contribute directly to regulatory predictability, effectiveness, and efficiency. Early identification and resolution of policy issues enhance technical and regulatory readiness and communications. Some policy issues are for the NRC staff to address, while others may require engagement with the Commission.

The NRC public Web site lists the policy issues the NRC staff is considering in relation to the licensing of SMRs and non-LWRs. The NRC staff revises this list routinely to reflect the latest updates on each policy issue. The NRC staff has discussed these issues with stakeholders in several of its recurring public meetings. These discussions will continue, so that the NRC receives ongoing stakeholder input on identifying, prioritizing, and resolving policy issues.

6.2 Progress Summary

6.2.1 10 CFR Part 53 Rulemaking

On January 14, 2019, the President signed NEIMA into law. NEIMA directs the NRC to develop the regulatory infrastructure to support the development and commercialization of advanced nuclear reactors. As stated in NEIMA, the statute aims, in part, to provide "a program to develop the expertise and regulatory processes necessary to allow innovation and the commercialization of advanced nuclear reactors." Section 103(a)(4) of NEIMA directs the NRC to "complete a rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications" by December 31, 2027. Because NEIMA gave the NRC discretion on the content and scope of the rulemaking, the NRC staff sought Commission approval of the proposed scope in SECY-20-0032, "Rulemaking Plan on 'Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062),'" dated April 13, 2020.[50] The NRC staff proposed a rulemaking that would build on previous agency efforts in this area, including the work done under the LMP, described in NEI 18-04, Revision 1, and endorsed by the NRC in Regulatory Guide 1.233. The rulemaking would create 10 CFR Part 53, in keeping with the NRC vision and strategy report and the statutory provisions in Section 103(a)(4) of NEIMA.

On October 2, 2020, the Commission issued SRM-SECY-20-0032, in which it approved the NRC staff's overall approach but directed the NRC staff to complete the rulemaking by 2024 instead of 2027, while still producing a high-quality, thoroughly vetted regulation. The Commission further directed the NRC staff to provide a schedule with milestones and resource requirements to achieve publication of the final rule by October 2024 and to inform the Commission of key uncertainties that might affect publication by that date. Finally, the Commission directed the NRC staff to consider the appropriate treatment of fusion technologies in the NRC's regulatory structure by developing options on licensing and regulating fusion energy systems for Commission consideration. In a memorandum dated November 2, 2020,[51]

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50 See ADAMS Accession No. ML19340A056.

51 See "Response to Staff Requirements—SECY-20-0032—Rulemaking Plan on 'Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062)'" (ADAMS Accession No. ML20288A240).

the NRC staff provided the Commission with the requested schedule, including milestones and resource requirements, as well as the list of key uncertainties affecting publication.

In 2021, the NRC staff developed preliminary proposed rule language for all of 10 CFR Part 53, aiming to produce an innovative, predictable, yet appropriately flexible framework with regulations encompassing various attributes of advanced reactor technologies, prioritizing RIPB licensing approaches to ensure public health and safety throughout the life of a facility. In accordance with Commission direction in SRM-SECY-20-0032, the NRC staff developed the proposed rule by intermittently releasing new preliminary language, engaging stakeholders, and producing additional iterations of the language. The NRC staff engaged stakeholders and the ACRS in over 20 public meetings to develop the draft proposed rule. In July 2021, in accordance with Section 103(e) of NEIMA, the NRC staff submitted to the Commission a SECY paper with a draft report to Congress regarding the completion schedule for the 10 CFR Part 53 rulemaking. This report also confirmed that the NRC has adequate expertise, modeling, and simulation capabilities, or access to those capabilities, to support the evaluation of anticipated commercial advanced reactor license applications.

Consistent with the Commission's Policy Statement on the Regulation of Advanced Reactors (73 FR 60612; October 14, 2008),[52] 10 CFR Part 53 would establish a transformative regulatory framework for advanced reactors that ensures protection of public health and safety and the common defense and security to at least the same degree as is required for current-generation LWRs under 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." In accordance with Commission direction in SRM-SECY-10-0121, "Staff Requirements—SECY-10-0121—Modifying the Risk-Informed Regulatory Guidance for New Reactors," dated March 2, 2011, 10 CFR Part 53 relies on the agency's existing safety goals, safety performance expectations, and associated guidance. However, 10 CFR Part 53 would replace the prescriptive nature of the current requirements with a technology-inclusive, RIPB framework. In addition, 10 CFR Part 53 would fully realize the Commission's policy that "[t]he use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy" (60 FR 42622; August 16, 1995). Thus, 10 CFR Part 53 would allow credit in the form of operational flexibilities when an advanced reactor design can show increased margins of safety, including slower transient response times and relatively small and slow release of fission products. The NRC staff views 10 CFR Part 53 as the next logical step in the evolution of the RIPB approach to regulation, which began as far back as the 1970s.

As noted previously, the NRC staff has performed extensive stakeholder outreach during the rulemaking process. The NRC staff spent over 80 hours in 12 public meetings on Part 53 and over 80 hours in 13 meetings with the Advisory Committee on Reactor Safeguards Full Committee and the Future Plant Designs Subcommittee. Over 170 public comment submittals have been received on the preliminary proposed rule language. While some stakeholders support the general direction of the rule, others, believing the rule language is overly complex and would increase regulatory burden, have expressed the desire to see changes.

The NRC staff is developing 10 CFR Part 53 in accordance with the rulemaking plan approved by the Commission. In particular, to develop performance criteria, it has leveraged the risk-informed approaches to design and licensing advanced reactors through joint activities of

[52] See ADAMS Accession No. ML082750370.

the industry, the DOE, and the NRC, such as the Next Generation Nuclear Plant Project and the LMP. However, the NRC staff has also made several changes in response to external stakeholder feedback, as highlighted in the following paragraphs.

Most significantly, stakeholders have requested that the NRC make a more traditional, deterministic licensing framework available for advanced reactors, and the NRC staff is pursuing such an alternative framework in parallel with the RIPB approach of 10 CFR Part 53. This alternative deterministic option more closely aligns with licensing methodologies used in international standards to allow flexibility for future applicants. This alternative was discussed at an October 28, 2021, public meeting. The NRC staff has also established a working group to develop a dose-based deterministic approach and discussed its approach at an advanced reactor stakeholder meeting on November 10, 2021. The NRC staff is also exploring a technology-inclusive, risk-informed maximum accident approach as an alternative to the use of PRA in developing the licensing basis. Other changes in response to external stakeholder feedback include eliminating the “two-tier” structure of the safety criteria (this was also an ACRS request), decoupling the requirements for normal operation from the requirements to address accidents and transients, adding references to Part 20 (this will be supplemented by development of draft guidance that allows a performance-based approach with more reliance on operational programs and less reliance on the NRC staff’s review of design features), and formulating quality assurance (QA) requirements to allow use of a broader set of codes and standards while consolidating all the QA requirements in one place (similar to 10 CFR Part 50 Appendix B). In addition, the NRC staff plans to include additional discussion in the rulemaking package on how possible surrogate measures, similar to core damage frequency for LWRs, could be used to satisfy the proposed requirements related to the quantitative health objectives. The NRC staff has made changes in response to feedback from the ACRS, such as adding requirements that safety analyses demonstrate that reactors achieve and maintain a safe, stable end state after design-basis accidents, and that all reactors be able to achieve a subcritical condition both during normal operation and after a licensing-basis event. After considering both internal and external feedback, the NRC staff is working to release one package for all of 10 CFR Part 53 in February 2022 to help stakeholders understand how the subparts work together to protect public health and safety.

Based on the stakeholder feedback described above, the NRC staff requested a nine-month extension to the current schedule for the 10 CFR Part 53 rulemaking in October 2021. The NRC staff requested the extension to address several issues that the NRC staff had identified as key challenges in its November 2020 memorandum to the Commission. Those issues included (1) providing additional time for the NRC staff to continue efforts to interact with external stakeholders and further develop rule language, (2) allowing additional time for external stakeholders to participate constructively in the rulemaking process, and (3) ensuring better coordination with other NRC advanced reactor activities. On November 23, 2021, the Commission approved the NRC staff’s extension request. Under the approved extension, the NRC staff will provide the Part 53 proposed rule package to the Commission by February 2023 and provide the final rule package, including key guidance, to the Commission by December 2024. The NRC staff is expecting to issue the final rule by July 2025, which is well ahead of the NEIMA requirement of December 2027. Further details about the basis for the schedule extension can be found in a note to Commissioners' Assistants, "Proposed Revisions to Schedule Milestones for Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (Part 53) Extension Request.”[53]

[53] See ADAMS Accession No. ML21333A222.

Consistent with the NRC Vision and Strategy for Safely Achieving Effective and Efficient Non-Light-Water Reactor Mission Readiness, guidance being developed to support 10 CFR Part 53 will provide an RIPB framework that calls for staff review efforts commensurate with the risks posed by the design under consideration. Other sections of this enclosure discuss this guidance further.

As well as working on preliminary proposed rule language related to safety for 10 CFR Part 53, the NRC staff is creating a transformative security framework for advanced reactors that ensures at least the same degree of protection as is required of current-generation LWR security programs. To determine the appropriate level of security for advanced reactors, commensurate with the risks of activities involving special nuclear materials (including higher enriched fuels), the NRC staff is building on the existing regulatory framework and implementation experience with security programs for power reactors, non-power reactors, and fuel manufacturing facilities. The proposed framework allows for advanced reactor designs to incorporate security upfront or security by design. It applies a graded approach to a comprehensive range of security areas, including physical security, fitness for duty, access authorization, and cybersecurity, commensurate with the corresponding risk to public health and safety. The NRC staff is keeping abreast of new technologies, trends, and emerging threat vectors to make sure that the regulatory infrastructure will provide clarity, stability, and protection in a dynamic environment. It is leveraging work from the rulemaking on emergency preparedness (EP) for SMRs and other new technologies (ONTs) to develop a consequence-based approach to security.

The NRC staff is developing companion security guidance to be issued with the proposed rule. This guidance will provide flexibility for the licensing of advanced reactors with enhanced safety and security features. The benchmark in the graded approach of the current RIPB security framework is that the potential radiological consequences of activities involving nuclear material do not pose unreasonable risk to public health and safety. Early and frequent stakeholder engagement has improved the NRC staff's understanding of public views, industry considerations, and other factors relevant to the development of this new regulatory approach.

Next steps: Consistent with the Commission-approved rulemaking schedule, the NRC staff will continue to engage stakeholders and the ACRS in 2022 to finalize the 10 CFR Part 53 proposed rule for Commission consideration in early 2023. The NRC staff will also continue to develop the preliminary language for the alternative, deterministic licensing framework to be included in the proposed rule package.

6.2.2 Siting for Small Modular Reactors and Non-Light-Water Reactors

In SECY-20-0045, "Population Related Siting Considerations for Advanced Reactors,"[54] dated May 8, 2020, the NRC staff presented the Commission with several options for addressing questions on population-related siting. The NRC staff recommended revising NRC guidance to provide an alternative population density criterion that is directly related to the potential radiological consequences estimated for a range of possible design-specific events.

Next steps: The Commission is reviewing SECY-20-0045. The NRC staff will implement the Commission's directions after issuance of the SRM.

[54] See ADAMS Accession No. ML19262H055 (package).

6.2.3 Emergency Preparedness Requirements for Small Modular Reactors and Other New Technologies

Consistent with the Commission's direction in 2015, the NRC staff developed a proposed rule providing alternative EP requirements for SMRs and ONTs, following a consequence-oriented, RIPB approach. This rulemaking would reduce potential requests for exemptions from the current EP requirements and would promote regulatory stability, predictability, and clarity in the licensing process for future facilities. Along with the proposed rule, the NRC staff developed draft guidance in DG-1350, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," issued May 2020. DG-1350 includes methods and procedures for demonstrating compliance with performance-based EP requirements and a methodology to inform the size of the plume exposure pathway emergency planning zone.

The NRC staff published the regulatory basis for the rulemaking on November 15, 2017 and presented the proposed rule for Commission consideration in SECY-18-0103, "Proposed Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies (RIN 3150-AJ68; NRC-2015-0225)," dated October 12, 2018.[55] On December 17, 2019, in SRM-SECY-18-0103, the Commission approved publication of the proposed rule. On May 12, 2020, the NRC published the proposed rule with a 75-day public comment period (85 FR 28436). On June 24, 2020, the NRC staff hosted a public meeting to answer questions about the proposed rule and guidance document, then extended the public comment period to September 25, 2020.

Next steps: The NRC staff received over 2,000 public comments, which it reviewed and considered in the formulation of a proposed final draft rule and associated guidance. The NRC staff submitted the draft final rule for Commission review and approval on January 3, 2022.

6.2.4 Appropriate Source Term and Dose Calculations for Small Modular Reactors and Non-Light-Water Reactors

In SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-light Water Reactors,"[56] dated February 7, 2016, the NRC staff stated that the evaluation of mechanistic methods would be important for application reviews, and that it did not note concerns or policy issues related to the implementation of mechanistic accident modeling of source terms. Specifically, the NRC staff affirmed that although it has not yet developed source term tools and technical expertise for non-LWRs to the same level as for LWRs, it believes a mechanistic approach could also be applied to non-LWRs, given adequate tools and methods of analysis.

In a letter dated October 19, 2018, the ACRS stated that the NRC staff "should provide [mechanistic source term] guidance to evaluate the adequacy of the frequency of events considered and the duration over which such events must be analyzed," as well as guidance "on how source terms should be developed." In a response dated November 9, 2018, the NRC staff stated that it would continue to evaluate the need to enhance its guidance on mechanistic source term (MST) development. Subsequently, NEIMA specified that the NRC should develop and implement guidance on MST use by January 2021.

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55 See ADAMS Accession No. ML18134A086 (package).

56 See ADAMS Accession No. ML15309A319.

The NRC contracted with INL to produce a report summarizing existing technology-inclusive and RIPB approaches to developing source terms for dose-related assessments at advanced nuclear facilities. INL issued the final report, INL/EXT-20-58717, "Technology-Inclusive Determination of Mechanistic Source Terms for Offsite Dose-Related Assessments for Advanced Nuclear Reactor Facilities," in June 2020.[57] The report outlines graded technical approaches to the development of design-specific MSTs, including previous approaches such as that of the Next Generation Nuclear Plant Project; it also describes how MSTs are used in the methodology of NEI 18-04 and RG 1.233. The report does not provide MST methodologies or assumptions for the various advanced reactor technologies under development.

The NRC staff has continued interactions with potential non-LWR applicants on related MST methodologies that account for the retention of radionuclides by barriers and the transport of radionuclides for all barriers and pathways to the environment. As previously stated, the NRC supports the use of MSTs, as evidenced by documents such as "Next Generation Nuclear Plant Licensing Strategy: A Report to Congress," issued August 2008,[58] and, more recently, the final safety evaluation report for the NuScale design certification.

To support the use of MSTs, the NRC staff is conducting an endorsement review for the ASME/ANS non-LWR PRA standard, ASME/ANS RA-S-1.4. This standard provides a way to determine source terms; it references the calculation guidance in RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," issued July 2000.[59]

The NRC staff is also interacting with stakeholders and engaging the national laboratories to support the use of MSTs by advanced reactor developers. In 2021, with support from ORNL and Sandia National Laboratories, the NRC staff conducted workshops to demonstrate the application of its MELCOR and SCALE codes to three reference plants: a heat pipe reactor, an HTGR, and a molten-salt-cooled PBR. The NRC uses MELCOR and SCALE to simulate reactor accidents, including the release of radionuclides from fuel and radionuclide retention or attenuation by plant systems and structures, in order to obtain insight into reactor safety and assess accident mitigation strategies.

Next steps: In February 2022, the NRC staff plans to brief the ACRS Future Plant Designs Subcommittee on integration of source term activities in support of advanced reactor initiatives. Also, the NRC staff plans to hold public meetings in 2022 to discuss its approach to assessing source terms for non-LWR technologies with stakeholders.

6.2.5 Security and Safeguards Requirements for Small Modular Reactors and Non-Light-Water Reactors

On August 1, 2018, the NRC staff issued SECY-18-0076, "Options and Recommendation for Physical Security for Advanced Reactors."[60] In its SRM dated November 19, 2018, the Commission directed the NRC staff to initiate a limited-scope revision to regulations and guidance on physical security for advanced reactors; it also approved, subject to edits, a related rulemaking plan. The NRC staff prepared a regulatory basis, which was released for public comment on July 16, 2019 (84 FR 33861). The NRC staff released preliminary proposed rule language twice and held public meetings in 2020 to discuss the rule text and its disposition of

57 See ADAMS Accession No. ML20192A250.
58 See ADAMS Accession No. ML082290017.
59 See ADAMS Accession No. ML003716792.
60 See ADAMS Accession No. ML18170A051 (package).

public comments. The preliminary proposed rule language sets forth alternatives to certain existing security requirements in 10 CFR 73.55, "Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage," that, in their current format, may not be appropriate for all advanced reactors. It also sets forth eligibility criteria that advanced reactor licensees must meet before using one or more of these alternative security requirements.

In 2021, the NRC staff continued developing the NRC's draft implementation guidance to support this limited scope security rule. This included reviewing NEI draft guidance in NEI 20-05, "Methodological Approach and Considerations for a Technical Analysis to Demonstrate Compliance with the Performance Criteria of 10 CFR 73.55(a)(7)," which focuses on the eligibility criteria in the preliminary proposed rule language. On March 5, 2021, the NRC staff issued a letter to the NEI containing its comments on Draft B of NEI 20-05.[61] In May 2021, the NEI submitted Draft D of NEI 20-05 for staff review. On October 29, 2021, after public discussions on the topic, the NEI requested that the NRC staff cease its review of NEI 20-05. The NEI stated that since the rule language is still evolving, it is likely more efficient for the NRC staff to write the guidance, soliciting comments from the public and the industry during its development. The NRC staff is therefore developing new regulatory guidance in DG-1365 to implement the proposed alternative physical security requirements. Also, in parallel, the NRC staff is drafting DG-5071, a revision of RG 5.81, to address target set identification for advanced reactors.

The NRC staff held five public meetings in 2021 to discuss preliminary rule language and guidance. Initially the NRC staff was scheduled to submit the proposed rule and the draft guidance documents to the Commission in September 2021. However, in early September 2021, the NRC staff requested an extension because it had encountered unanticipated complexities in adapting a security framework designed for large LWRs to include a risk-informed, technology-neutral option for advanced reactors. The Commission approved the extension request on October 18, 2021; the proposed rule is now due for submission to the Commission in June 2022. The extra time will allow the NRC staff to fully consider diverse perspectives in finalizing the proposed rule and associated guidance, in order to balance security and regulatory considerations with an appropriate degree of flexibility in the framework.

Next steps: The NRC staff will continue to interact with stakeholders while completing the proposed rule and related guidance. The NRC staff will update DG-1365 to include guidance that NEI 20-05 would have covered. The NRC staff will provide a draft proposed rule on the alternative physical security requirements for advanced reactors to the Commission by June 28, 2022.

6.2.6 Insurance and Liability for Small Modular Reactors and Non-Light-Water Reactors

The NRC staff has discussed insurance and liability with stakeholders during several public meetings. The Commission's Policy Statement on the Regulation of Advanced Reactors states the following:

> Consistent with its legislative mandate, the Commission's policy with respect to regulating nuclear power reactors is to ensure adequate protection of the environment and public health and safety and the common defense and security. Regarding advanced reactors, the Commission expects, as a minimum, at least

[61] See ADAMS Accession No. ML21049A029 (package).

> the same degree of protection of the environment and public health and safety and the common defense and security that is required for current generation light-water reactors (LWRs). [In this context, "current generation LWRs" are those nuclear power plants licensed before 1997.] Furthermore, the Commission expects that advanced reactors will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions.

Given that advanced reactor regulations are expected to ensure at least the same degree of protection as the regulations for existing reactors, the question is whether (1) the risk profiles for advanced reactor facilities are comparable to those of existing facilities, for which the current insurance and liability requirements were established, or (2) advanced reactors have reduced risk profiles, which might warrant changes to insurance and liability requirements. To evaluate the first possibility, the NRC staff will document its assessments of the risks associated with advanced reactor facilities, including multimodule issues, as part of developing a regulatory framework for advanced reactors and during the licensing process for specific designs and facilities. As for the second possibility, in public meetings on this topic, stakeholders (including designers and industry organizations) have indicated that no immediate actions are called for to revise current insurance and liability requirements for advanced reactors. While the NRC does not envision a need for changes to the Price-Anderson Act, guidance updates or rulemaking may be necessary to develop a financial protection framework for advanced reactors, including the licensing of multimodule or multiunit designs and facilities.

On December 9, 2021, the NRC submitted NUREG/CR-7293, "The Price-Anderson Act: 2021 Report to Congress Public; Liability Insurance and Indemnity Requirements for an Evolving Commercial Nuclear Industry," to the U.S. Congress (ADAMS Accession No. ML21336A323).

6.2.7 Micro-reactors

Micro-reactors, which are generally small (on the order of 1 megawatt thermal to tens of megawatts thermal operating power), are envisioned to perform nontraditional roles for nuclear power, such as providing power for defense sites and remote areas. It is expected that micro-reactors will rely less on complex safety systems and more on inherent safety features, and that the potential consequences of any postulated accidents will be less severe. The NRC staff has identified several potential policy and licensing issues to address for micro-reactors, including the following:

- security requirements
- EP
- staffing requirements
- remote operation
- aircraft impact
- oversight
- annual fee structure
- manufacturing licenses
- transportable reactors
- siting
- environmental reviews

On October 6, 2020, the NRC staff provided SECY-20-0093, "Policy and Licensing Considerations Related to Micro-reactors,"[62] to the Commission. This paper (1) informs the Commission of licensing topics related to nuclear micro-reactors that may necessitate departures from current regulations, related guidance, and precedent, (2) identifies potential policy issues related to licensing micro-reactors, and (3) describes the NRC staff's approach to facilitating licensing submittals for near-term and future deployment and operation of micro-reactors.

On September 3, 2021, the NRC staff released a draft white paper outlining optional strategies for streamlining the licensing of anticipated micro-reactors.[63] These strategies leverage flexibilities in existing regulations and identify options for changes to regulatory requirements that could provide additional flexibilities, to the extent permitted under Commission policy and existing laws (e.g., the Atomic Energy Act of 1954, as amended). The strategies aim to maximize standardization and finality using design certification, standard design approval, and topical report approvals.

The white paper focuses on the following areas:

- enhanced standardization of the design (e.g., through the use of bounding design parameters in early site permits, bounding site parameters in design certification, and a minimal set of site-specific design features)

- use of manufacturing licenses to gain efficiencies at the combined license stage, and use of other regulatory requirements, such as those on possession of special nuclear material and transportation

- strategies for review of operational matters (e.g., technical specifications and operational programs) at the design stage, either as part of the design approval (to the extent allowed under Commission policy); through topical reports; or through a design-centered approach, in which the NRC staff would review operational matters for the first application for a particular microreactor design, then apply the review results to subsequent applications that handle operational matters in the same way

- rulemaking to streamline the environmental reviews of advanced reactor applications

The NRC staff discussed the white paper and obtained feedback in a meeting with advanced reactor stakeholders on September 29, 2021. The NRC staff addressed stakeholder feedback and released an updated white paper on December 3, 2021[64]

Next steps: In the near term, the NRC staff plans to license micro-reactors under the existing regulations in 10 CFR Part 50 and 10 CFR Part 52. Because of the significant differences between large LWRs and micro-reactors, the NRC staff is receptive to requests for exemptions from the existing regulations in the areas above and would evaluate such requests on a case-by-case basis using existing agency processes. Proposals in some of these areas (such as fully autonomous operation) may encompass policy issues that warrant future Commission interaction.

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62 See ADAMS Accession No. ML20254A363.
63 See ADAMS Accession No. ML21235A418.
64 See ADAMS Accession No. ML21328A189

In the longer term, the NRC is conducting rulemaking to establish the technology-inclusive regulatory framework required by NEIMA. The NRC staff expects this rulemaking to include provisions addressing micro-reactors in a manner commensurate with the risks they pose. The NRC plans to address issues such as annual fees in other planned rulemakings (e.g., the annual fee rule). The NRC staff, as discussed in the white paper, future rulemaking efforts could explore the streamlining of site hazards, operational programs, manufacturing licenses for fabrication and transportation, and environmental review.

6.2.8 Fusion Technologies

Since NEIMA defines "advanced nuclear reactor" as a nuclear fission or fusion reactor, including a prototype plant, the Commission has directed the NRC staff to develop ways to treat fusion technologies appropriately within the NRC's regulatory structure.

The NRC staff is considering three options, as part of its efforts to prepare a Commission paper on licensing and regulating commercial fusion power plants:

(1) a framework like that established for utilization facilities under the proposed 10 CFR Part 53

(2) a framework like that of 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," for byproduct material licenses

(3) a new or hybrid framework

With respect to the first option, while the NRC staff is currently considering fusion in its development of this rulemaking, changes would be necessary to address fusion power plants. However, many of the regulatory changes being considered for non-LWRs could also inform strategies for licensing fusion reactors.

The NRC staff's development of a framework for fusion regulation is on a separate schedule from its 10 CFR Part 53 rulemaking efforts. Therefore, should the NRC staff initiate a rulemaking to address fusion facilities, the schedule could extend beyond the Commission-approved deadline for 10 CFR Part 53; however, the rulemaking would be completed before the NEIMA deadline of 2027.

The NRC and the Fusion Energy Sciences program of the DOE Office of Science are interacting regularly to develop longer term strategies for the possible deployment of fusion reactors. The NRC staff supported a joint DOE/NRC workshop on fusion technologies in October 2020 and held numerous public meetings to solicit stakeholder feedback in 2021. In addition, the NRC staff briefed the ACRS on May 6, 2021 and held a public meeting with external stakeholders on development of a regulatory framework for fusion reactor applications on September 16, 2021.

Next steps: The NRC staff will continue to interact with key national and international stakeholders, such as the Fusion Industry Association, ASME, and IAEA, among others. The NRC staff plans to submit an options paper on licensing and regulating fusion energy systems for Commission consideration in the fall of 2022.

7.0 Strategic Area No. 6: Communication

7.1 Overview

This strategic area supports the objective of optimizing communications. The communications plan seeks to do the following:

- Provide timely, clear, and consistent communication of NRC requirements, guidance, processes, and other regulatory topics, and provide multiple paths for external feedback to the NRC.

- Develop consistent NRC messaging suitable for a range of audiences.

- Promote the exchange of non-LWR technical and regulatory experience with the NRC's international counterparts and industry organizations.

7.2 Progress Summary

The NRC continues to communicate with stakeholders and seek their feedback on all non-LWR readiness activities. The NRC also meets with prospective applicants upon request, and it shares information with various international groups, including the NEA (an agency under the Organisation for Economic Co-operation and Development (OECD)), the IAEA, the Generation IV International Forum, and the NRC's international regulatory counterparts. The sections below describe key accomplishments and ongoing activities.

7.2.1 Stakeholder Engagement

The NRC conducts public meetings with stakeholders every 6–8 weeks. In early 2020, to maximize participation in the regulatory process, the NRC staff made it possible for stakeholders to participate either in person or virtually. Since March 2020, because of the Coronavirus Disease 2019 (COVID-19) pandemic, the NRC staff has been conducting these public meetings virtually. The NRC staff conducted eight such meetings in 2021, in addition to topic-specific meetings on 10 CFR Part 53, the technology-inclusive and risk-informed regulatory framework, and ARCAP and TICAP guidance development.

The NRC has also briefed the ACRS Future Plant Subcommittee and Full Committee on various topics, including 10 CFR Part 53; the draft final rule on EP for SMRs and ONTs; fuel qualification for advanced reactors; RIPB human-system considerations for advanced reactors; potential endorsement of BPVC-III-5; the draft RG supporting ASME/ANS RA-S-1.4-2021; MSR fuel qualification; draft NUREG-2246 guidance for fuel qualification; the Kairos Power topical reports KP-TR---010, "KP--FHR Fuel Performance Methodology," issued December 2019, and KP-TR---012, "KP--FHR Mechanistic Source Term Methodology," issued June 2020; and Volumes 4 and 5 of the reports on advanced reactor computer codes.

Next steps: The NRC staff will hold stakeholder meetings approximately every 6 weeks in 2022. It will also hold public meetings on topical issues related to 10 CFR Part 53 and other ongoing rulemakings, and on ARCAP and TICAP guidance. It will conduct public exchanges with stakeholders on options for a regulatory framework for fusion technologies.

7.2.2 Coordination with the U.S. Department of Energy

The NRC interacts frequently with the DOE, consistent with the NRC's statutory authority, on activities related to regulatory development and to modernizing the NRC's regulatory framework to facilitate the licensing of advanced reactors. The NRC staff has been preparing to receive applications for advanced reactor designs, including two proposals to build advanced reactors arising out of DOE's Advanced Reactor Demonstration Program (ARDP), through which DOE selected two new advanced reactor designs and awarded funding to support fully functional advanced nuclear reactors within 7 years of the award. In October 2020, the DOE selected two teams, one led by TerraPower and the other by X-energy, to receive initial funding for ARDP demonstration projects, which will lead to applications within the next several years. In addition, the NRC staff is conducting pre-application interactions with advanced reactor vendors and, within the bounds of its statutory authority, working with DOE on its Risk Reduction for Future Demonstration Projects program and Advanced Reactor Concepts-20 program. In December 2020, the DOE selected five teams to receive initial funding under the Risk Reduction for Future Demonstration Projects program and three U.S.-based teams to receive funding under the Advanced Reactor Concepts-20 program. These awards have generated pre-application engagement for multiple advanced reactor designs. In 2020, the NRC and the DOE put in place an addendum to an existing memorandum of understanding (MOU) covering DOE and NRC roles and responsibilities in the ARDP. Additionally, the DOE has direction and funding to work with the NRC and to pursue regulatory development activities through the national laboratories. The NRC staff has been coordinating with the DOE and the national laboratories on the qualification of each of the fuel types under consideration by advanced reactor designers. In monthly calls, the NRC and the DOE discuss areas of mutual interest. They also hold periodic management meetings to share information about advanced reactor readiness activities.

An MOU is in place for the NRC and the DOE to work cooperatively within the bounds of their respective statutory authorities on the DOE authorization process for the proposed VTR. Under this MOU, the NRC and the DOE have discussed the DOE's experience in implementing the NRC's guidance in RG 1.233 and the National Environmental Policy Act process for assessing the environmental impact of the VTR. The NRC staff also participated in several workshops cosponsored by the DOE's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative, which are listed in Section 7.2.4 of this enclosure.

Another MOU allows the NRC and the DOE to share technical expertise and knowledge as required by NEICA. The primary purpose of this MOU is to coordinate DOE and NRC technical readiness and to facilitate sharing of expertise on advanced reactor technologies and nuclear energy innovation. This includes activities involving the National Reactor Innovation Center, which is a DOE program established under NEICA to enable the testing and demonstration of reactor concepts to be proposed and funded, wholly or in part, by the private sector. In 2021, the NRC and the DOE put in place three addenda to this MOU, covering DOE and NRC roles and responsibilities for (1) research, development, and demonstration projects undertaken by the National Reactor Innovation Center, (2) activities related to the characterization of radiological source terms and the development of the MELCOR code, and (3) advanced technologies for long-term operations and plant modernization.

The NRC and the Fusion Energy Sciences program of the DOE Office of Science are interacting regularly to develop longer term strategies for the possible deployment of fusion reactors.

Next steps: The NRC staff will continue to interact frequently with the DOE to gather information relevant to the NRC's non-LWR readiness activities. The NRC staff will also continue to support the GAIN initiative and attend GAIN workshops, as specified in the GAIN MOU. The NRC staff will continue to work with the DOE on the regulatory development activities in the NEICA MOU, consistent with the NRC's statutory authority. The NRC staff is outlining a new addendum to the NEICA MOU specific to fuel cycle activities. Lastly, in support of the ARDP, the NRC staff is ready to receive applications for multiple advanced reactor designs.

7.2.3 Coordination with the U.S. Department of Defense

The Strategic Capabilities Office (SCO) in the U.S. Department of Defense (DOD) is leading the mobile microreactor demonstration project, in collaboration with the DOE, the U.S. Army Corps of Engineers, and industry partners. In May 2019, the NRC, the DOE, and the SCO signed an MOU to coordinate technical readiness and share technical expertise and knowledge on microreactor technologies to support the DOD's research and development of micro-reactors. By participating in this project, the NRC aims to enhance its understanding of advanced reactor technologies and gain insights to inform its licensing approaches, consistent with its role as an independent safety and security regulator. Coordination is key to the rapid development of workable prototype designs that can support evaluation, safety analysis, and ultimately construction and testing. The MOU states that the DOE and its national laboratories will provide technical, environmental, siting, and safety-basis documentation support for the project. The NRC staff has contributed explanations of the agency's requirements and guidance when needed. In March 2021, the SCO selected BWXT Advanced Technologies and X-energy to develop a final design for the prototype mobile microreactor.

Next steps: The NRC staff will continue to cooperate with the DOD and the DOE, within the bounds of its statutory authority, to resolve the technical and policy issues associated with the successful demonstration of a mobile reactor.

7.2.4 Meetings and Conferences

To facilitate outreach and communications, the NRC holds periodic stakeholder meetings to discuss topics of interest related to non-LWRs. In 2021, the NRC staff actively participated in numerous workshops, conferences, and meetings, most of which took place virtually because of the COVID-19 public health emergency. These included the following events:

- Westinghouse eVinci Microreactor, TICAP tabletop exercise
- TerraPower Molten Chloride Reactor Experiment, TICAP tabletop exercise
- X-energy Xe-100, TICAP tabletop exercise
- VTR, TICAP tabletop exercise
- Probabilistic Flood Hazard Assessment Research Workshop
- seminars on graphite degradation, aging, and failure mechanisms relevant to ADVANCED NON-LWRs

- Microreactor Applications Research, Validation, and Evaluation (MARVEL) Project technology review webinar
- seminar on LWR ATF, HALEU, and non-LWR fuel concepts
- workshops on using the NRC's SCALE and MELCOR codes to develop source terms for heat pipe reactors, HTGRs, and molten-salt-cooled PBRs
- EPRI's Advanced Reactor Stakeholder Forum
- ANS Annual Meeting
- Workshop on Leveraging IAEA Safeguards Experience for U.S. Advanced Reactors
- IAEA Workshop on High Temperature Gas Cooled Reactor Technology
- IAEA Consultancy Meeting on Fusion Reactors
- Webinar on IAEA Applicability of IAEA Safety Standards to the Design of Novel Advanced Reactors Including SMRs
- GAIN-EPRI-NEI 2021 Virtual Molten Salt Reactor Workshop
- GAIN-EPRI-NEI Advanced Materials and Manufacturing Technologies Virtual Workshop
- quarterly ASME meetings
- NRC 2021 Codes and Standards Forum
- meetings of the OECD/NEA Working Group on the Safety of Advanced Reactors

Next steps: The NRC will continue to participate in non-LWR meetings, conferences, seminars, and workshops as resources permit.

7.2.5 International Coordination

As part of the NRC's goal of continuing to be a modern risk-informed regulator and building strong partnerships, as well as optimizing resource use and leveraging experience, the NRC staff engages and cooperates extensively with international organizations, including the OECD/NEA, the IAEA, the Generation IV International Forum, and the NRC's international regulatory counterparts.

The NRC chairs the NEA's Working Group on the Safety of Advanced Reactors, in which international regulators exchange information on technical topics related to the safety and regulation of non-LWRs. As part of this working group, the NRC staff is leading a task group to study common regulatory practices to ensure appropriate qualification and through-life performance of materials in advanced reactors. In 2021, the Working Group on the Safety of Advanced Reactors completed reports on regulatory approaches to fuel qualification, which formed the foundation of the NRC's draft guidance in this area, and regulatory perspectives on analytical codes and methods for advanced reactors.

The NRC staff is also participating in several experimental programs under the NEA Committee on the Safety of Nuclear Installations. More specifically, the NRC chairs and participates in the Loss of Forced Coolant Joint Project which gives the NRC access to HTGR data from the Japanese High-Temperature Engineering Test Reactor and to natural circulation data from integral test facilities, which could improve the agency's confirmatory analysis capability. With the NRC's leadership over the last year, the project was restarted after being shut down for several years to perform Fukushima related upgrades to the facility. The remaining two tests will be completed in 2022.

The NRC staff has access to research and testing activities through bilateral agreements with international regulators. Since 2018, the NRC has built strong international partnerships on materials research, which have led to significant information exchange and increased the agency's knowledge, data, and international experience. Notable examples of these partnerships include the technical exchanges with the United Kingdom on the use of graphitic components; with Japan on high-temperature materials and surveillance programs; and with the Czech Republic on molten salt purity, best practices, and materials compatibility.

The NRC participates in and chairs the IAEA SMR Regulators' Forum, in which regulators identify and address key regulatory challenges to SMR oversight. Established in 2015, the forum has completed projects on emergency planning zones; the principles of graded approaches and defense in depth; and manufacturing, commissioning, and operations. In 2021, the forum issued several reports on licensing, safety analysis, and manufacturing oversight of SMRs, including "Framework for Mutual Recognition of Regulators' Assessment," "Capabilities of the Supply Chain When Supporting Licensees," and "Implications of SMR Deployment on Configuration Management."[65] The forum has continued expanding its international platform for the understanding of SMR designs, licensing applications, and safety standards. Phase III of the project covers new topics such as the framework for international collaboration and joint assessments; the integration of security, safeguards, and safety-by-design principles; and regulatory considerations in pre-licensing engagement for long-lead requests and items.

The NRC staff is actively participating in an IAEA effort to review the applicability of IAEA Safety Standards to different power reactors including light-water SMRs and non-LWRs. A review was completed in October 2021 by the IAEA supported by a team of 150 international experts, from 30 member states and 40 organizations including regulatory bodies and technical safety organizations. The IAEA coordinated this effort with the various safety standards committees and the SMR Regulators' Forum. The NRC participated in a series of three consultancy meetings in 2021. The outcomes of this work have been captured in an IAEA report that provides a mapping of areas of the safety standards that are technology neutral and applicable to all types of advanced reactors and identifies gaps in applicability. This work provides the basis for the development of a prioritized IAEA program of work to address gaps.

In August 2019, the NRC entered into a memorandum of cooperation with the CNSC to expand interaction on advanced reactor and SMR activities, including the development of shared technical review approaches, pre-application activities, research, training, and the development of regulatory approaches addressing unique and novel technical considerations relevant to safety. The NRC and the CNSC agreed to implement the memorandum of cooperation under the existing NRC-CNSC Steering Committee, under which staff members from both agencies have already discussed these topics and the potential for future cooperation.

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[65] These reports are publicly available at https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum.

At its October 2019 meeting in Ottawa, Canada, the Steering Committee approved terms of reference for a new Subcommittee on Advanced Reactor Technologies and Small Modular Reactors. This subcommittee has held three formal meetings, in October 2019, March 2020, and September 2020; it currently meets every 4–6 weeks. It has approved work plans for six collaborative projects:

(1) development of common guidance for the contents of new-build license applications for advanced reactor projects

(2) sharing of regulatory insights from the technical review of the NuScale SMR design certification review

(3) a review of X-energy's request for informal feedback on its reactor pressure vessel construction code assessment for the Xe-100 design

(4) a review of Terrestrial Energy's white paper on postulated initiating events

(5) a review of the licensing topical report on the BWRX-300 Containment Evaluation Method

(6) establishment of a common regulatory position on TRISO fuel qualification

The projects will produce joint reports that contain feedback and positions from both the NRC and the CNSC, which may leverage them in their respective regulatory reviews and decision-making.

In June 2021, the NRC and the CNSC signed their first joint report, on pre-licensing-review activities for advanced reactors. The report documents the two agencies' collaborative review of X-energy's request for informal feedback on its reactor pressure vessel construction code assessment for the Xe-100 design.[66] The report was publicly released on August 11, 2021 and was posted on the NRC's public Web site and advertised through social media in coordination with the Office of Public Affairs, the Office of International Programs, and the CNSC.

On August 12, 2021, the CNSC and the NRC issued their second joint report, on technology-inclusive, risk-informed reviews for advanced reactors.[67] This report gives a broad overview of the NRC and CNSC regulatory frameworks and compares the LMP, as endorsed in RG 1.233, with the CNSC approach.

In September 2021, the NRC and the CNSC mutually agreed to invite the UK's Office for Nuclear Regulation (ONR) to observe the collaborative activities for TRISO fuel and the ONR accepted. The NRC will leverage the existing bilateral Memorandum of Understanding with the ONR to enable this outreach and initiative with the UK.

Next steps: The NRC will continue to foster international cooperation by exchanging information with international counterparts and participating in NEA and IAEA working groups. The NRC and the CNSC will continue frequent bilateral interactions under their memorandum of cooperation.

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66 See ADAMS Accession No. ML21166A304.

67 See ADAMS Accession No. ML21225A101.