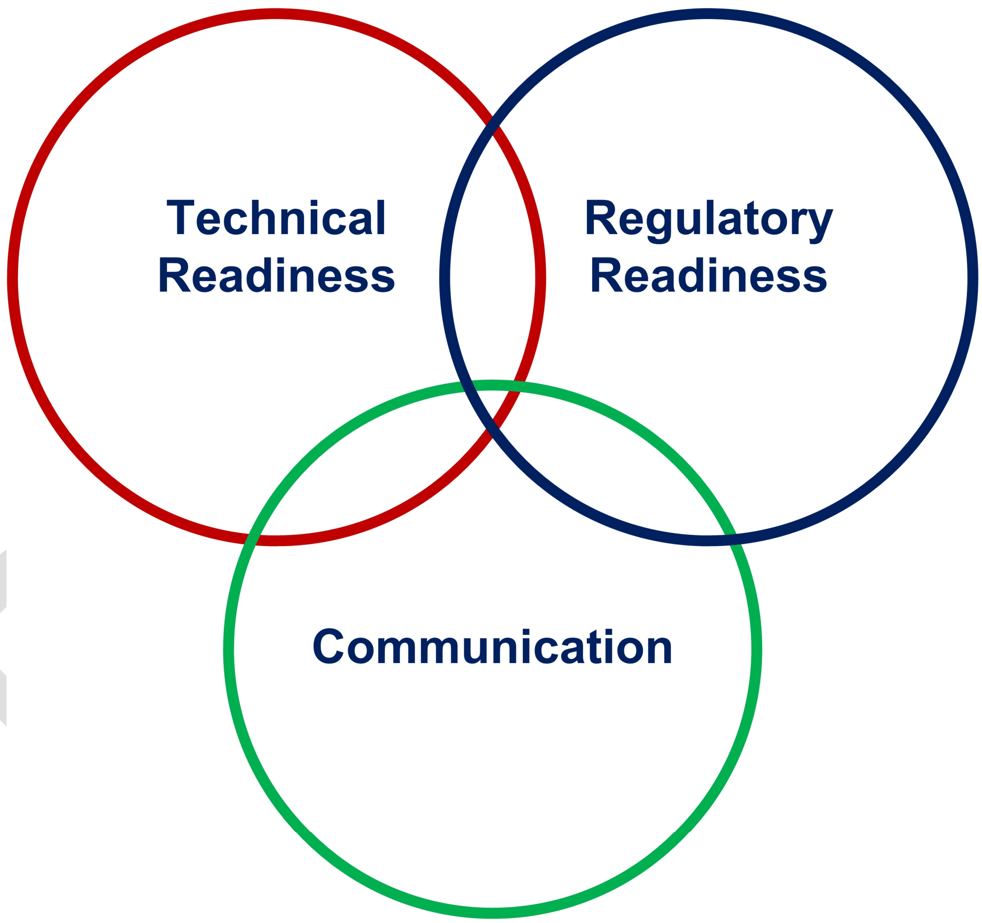
Draft – April 1, 2019

Code Assessment Plans for NRC's Regulatory Oversight of Non-Light Water Reactors



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ABBREVIATIONS AND ACRONYMS

Abbreviation	Definition
ATF	Accident Tolerant Fuel
BDBA	Beyond Design Basis Accidents
CASL	Consortium of Advanced Simulation of Light Water Reactors
DBA	Design Basis Accident
DOE	U.S. Department of Energy
GCR	Gas-Cooled Reactor
LMP	Licensing Modernization Plan
LWR	Light Water Reactor
MSR	Molten Salt Reactor
NEAMS	Nuclear Energy Advanced Modeling and Simulation
NGNP	Next Generation Nuclear Plant
NRC	U.S. Nuclear Regulatory Commission
PRA	Probabilistic Risk Assessment
RELAP	Reactor Excursion and Leak Analysis Program
SFR	Sodium Fast Reactor

EXECUTIVE SUMMARY

In December 2016, the U.S. Nuclear Regulatory Commission (NRC) published "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness" [1]. This non-light water reactor (LWR) vision and strategy document provides a connection to other NRC mission, vision, and strategic planning activities, and describes the objectives, strategies, and contributing activities necessary to achieve non-LWR mission readiness. It also comprises a planning tool that describes: 1) what work must be done to achieve non-LWR licensing readiness, 2) how the work should be sequenced, 3) how to prepare the workforce, and 4) considerations for organizing work execution for maximum effectiveness and efficiency. The non-LWR vision and strategy approach consists of six specific strategies as described in the "NRC Non-Light Water Reactor Near-Term Implementation Action Plans" [2]. The main objectives of "Strategy 2" are to identify and develop the tools and databases that will optimize regulatory readiness and assist the staff in performing its safety reviews of non-LWR license applications. Central to Strategy 2 are the selection and development of computer codes to be used for non-LWRs. In some areas, the staff uses computer models and other analytical resources to conduct its review of non-LWR designs. The emphasis in the staff's approach for non-LWR computer codes is to leverage, to the maximum extent practical, collaboration and cooperation with the domestic and international communities interested in non-LWRs with the goal of establishing a set of tools and data that are commonly understood and accepted.

The staff has developed plans as described in this report that identify the work necessary to ensure that the computer codes and other analytical tools are ready to support the future licensing of non-LWR design, in the event NRC confirmatory analysis is needed. The purposes of this report are to provide an overview of the staff's recommended code development approach to support the licensing of non-LWRs; describe the factors considered for code selection and prioritization of code development activities; and obtain stakeholder feedback to inform NRC's ultimate decisions. Many of the staff's code development activities involve collaborative efforts with the Department of Energy and the National Laboratories. The source term, severe accident, and accident progression code development activities leverage U.S. Department of Energy (DOE) funded New Generation Nuclear Plant (NGNP) program activities for high temperature gas cooled reactors (GCRs) and international partnerships through the NRC's Cooperative Severe Accident Research Program code sharing program. Separate volumes have been developed to describe the staff's code development plans needed to support non-LWR licensing and regulatory oversight activities. More specifically, there are currently two Volumes that describe plans for the development of confirmatory analysis capabilities for traditional design basis scenarios (Volume 1 and accidents that may lead to offsite consequences (Volume 3). Additional volumes are being developed and will be published as NRC's understanding of the non-LWR designs progresses and industry's plans evolve.

This report and associated volumes represent the staff's current thinking given the uncertainty regarding industry priorities for licensing non-LWRs. Accordingly, the staff will modify its plans as the licensing needs and priorities evolve and become clearer to the staff over time. This overview and the associated volumes will be used to obtain feedback from internal and external stakeholders.

1.0 INTRODUCTION

There is significant interest in the development of non-LWR technologies because they offer the potential for enhanced safety, reliability, proliferation resistance, and improved economics. This interest is spurred by several pieces of legislation including the “Nuclear Energy Innovation Capabilities Act” signed into law on September 24, 2018, [3] and the “Nuclear Energy Innovation and Modernization Act” signed into law on January 14, 2019, [4]. These laws along with financial support from other federal agencies such as the DOE and the U.S. Department of Defense have spurred substantial industry interest in the development of a wide variety of non-light water reactor technologies that include sodium fast reactors (SFR), GCRs, molten salt reactors (MSR), and “micro” reactor designs. There are a substantial number of companies who have varying plans and experience developing non-LWR designs, some of which are more mature than others. Additionally, the non-LWR industry has become globalized and commercial non-LWR plants are being designed, constructed, and operated abroad.

Thus, the NRC is operating in an environment where potential non-LWR applicants have a wide and varied range of technical, business, and regulatory experience. Additionally, the NRC is facing challenging times that require it to improve its regulatory practices and make more efficient use of its resources, which includes the strategy and planning for the development of computer codes and tools to support non-LWR regulatory oversight.

In 2016, NRC responded accordingly and developed a vision and strategy to safely achieve effective and efficient mission readiness. In December 2016, the NRC published the “NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness” document, and in July 2017, the “NRC Non-Light Water Reactor Near-Term Implementation Action Plans” (IAP) were published [2]. One of the primary objectives of Strategy 2 of the IAP is the development of codes suitable for confirmatory analysis of GCRs, SFRs, MSRs, and “micro” reactors. Modeling and simulation of these designs involve certain physical processes and phenomena that generally do not occur in LWRs. Therefore, initial efforts have been directed at understanding requirements for modeling and simulation of these new designs, and in identifying codes that either meet or could meet these requirements. Codes used by the NRC for confirmatory analysis have been designed and assessed largely for LWRs. More specifically, the codes used for design basis accident (DBA) analyses are not immediately extendable to these non-LWR designs although some code development work was completed to add beyond design basis accidents (BDBA) analyses capability to MELCOR for high temperature GCRs under the NGNP. In some cases, the NRC codes could be made applicable with relatively modest investment, while in other cases the NRC codes are unsuitable and cannot be modified to be applicable without an extensive effort. Therefore, codes developed outside of the NRC were also considered. Specifically, codes developed under the Consortium of Advanced Simulation of LWRs (CASL) and Nuclear Energy Advanced Modeling and Simulation (NEAMS) possess some unique and advanced modeling capabilities that may be adopted for NRC use. The NRC has a Memorandum of Understanding with DOE on the cooperative use of modeling and simulation tools to support licensing of advanced reactor applications [5].

The staff has been participating in many NRC, DOE, National Laboratory, and industry led meetings to better understand the non-LWR designs that are being proposed and the analytical tools that are being developed. As such, the staff is aware of the potential for non-LWR developers to leverage advanced modelling and simulation capabilities in addition to using legacy codes for their design efforts and to support the development of the safety bases for those designs. Continued NRC staff participation in such meetings is important because it will enable to the staff to modify its code development plans as the industry’s strategies and plans evolve.

This report currently contains two Volumes that describe the development of confirmatory analysis capabilities for traditional design basis scenarios (Volume 1) and accidents that may lead to offsite consequences (Volume 3). These volumes contain information that provide descriptions of the codes, the potential regulatory application or uses of the codes, the bases or rationale for selecting the codes, the suite of codes proposed for use by the NRC for the various non-LWR reactor technology types, the maturity of the codes relative to their ability to be used for regulatory purposes, information and analytical gaps, and the tasks necessary to fil those gaps. The information contained in each of the volumes represents resource efficient code development plans at the time of the writing of this report. As the details of advanced reactors become known to the staff, these plans will change as appropriate. Additional volumes covering other code development areas (e.g., radiation protection (health physics), siting review dose assessment, materials, and component integrity) and analytical tools may be developed as NRC’s understanding of the non-LWR designs progresses and industry’s plans evolve.

2.0 REGULATORY USE OF ANALYTICAL CODES

The NRC uses computer codes to model and evaluate safety issues associated with the licensed use of radioactive materials. More specifically, NRC uses codes for a wide range of regulatory applications including: confirmatory analyses for initial licensing reviews; subsequent confirmatory analyses to support reactor design changes; siting evaluations; emergency response; the development of technical bases in support of rulemakings; and the development of specialized safety studies such as for the State-of-the-Art Reactor Consequences Analysis [6]. There are also a number of less tangible and equally important benefits of the NRC’s code related activities including developing technical expertise of staff which is often used to respond to complex technical and safety significant issues identified. Results from applying the codes support decision making for risk-informed activities, review of licensees' codes and performance of audit calculations, and resolution of technical issues. The use of these codes enables the staff to examine safety margins and ensure public safety in regulatory decisions and emergency response.

2.1 Confirmatory Analysis

The definition of “confirmatory analysis” is not explicitly established in NRC regulations or guidance. Additionally, there is no requirement for the NRC to conduct confirmatory analysis.

Various NRC documents refer to confirmatory analysis as independent calculations or analysis, or confirmatory assessments. In general, these phrases all refer to the same thing: staff-performed analysis that can be used to confirm portions of the licensee's or applicant's licensing basis as a part of its holistic review to assist in reaching a reasonable assurance determination.

Examples of areas where confirmatory analyses are discussed can be found throughout NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," [7] in areas such as containment thermal hydraulic analysis, nuclear design, fuel design, systems analysis, dose analyses, and severe accident scenario response analyses. The scope and level of detail of any confirmatory analyses to be performed varies based on factors further discussed below. In general, staff is expected to use judgement to assess the need for specific confirmatory analysis in the context of the overall safety review.

Confirmatory analysis is one means to support the staff to effectively identify and focus a licensing review on the most important risk and safety areas. This also has the additional benefit of helping further familiarize the staff with the design, which allows for more effective staff review in other areas. Staff confirmatory analyses, therefore, are expected to be focused on:

- Applications with novel design features where sufficient historical demonstration associated with NRC review and approval of such design features does not exist;
- Areas where uncertainty is relatively high or margins are small, such that the staff determines it is necessary to confirm the licensee's or applicant's prediction of responses to postulated accidents for a structure, system, and/or component;
- Analyses where sensitivity studies are performed to better understand the phenomena of interest leading to a more efficient means of advancing the review (such as investigating the importance of a key parameter on the results); and,
- Licensee or applicant deviations from an acceptable method (i.e., proposing an alternative method) cited in NRC guidance and the licensee's or applicant's design bases documents, or justifications provided in the application that raise fundamental safety concerns.

The staff weighs the need for confirmatory analysis, as described above, with the balance of the information in the licensing application. In cases where other parts of the application may address some of the above factors, the need to perform confirmatory analyses should consider the overall risk and safety significance of the design feature or phenomena of interest.

It is important to note that when performed, confirmatory analysis should be independent of the applicant's or licensee's analysis, although it is not a requirement for the staff to use different tools relative to the applicant's. If the applicant's analytical approach and methods have a sufficiently demonstrated validation base for the phenomena of interest, the tool used by the applicant and the staff could be the same.

In an environment where review timelines and resources are expected to be commensurate with the decreased risk and enhanced safety of non-LWRs, it is important that the staff's review be focused on areas with the largest potential safety impact. Effective use of confirmatory analysis may play an important role in making a reasonable assurance determination. Ultimately, the applicant or licensee's calculations are the analysis of record for the licensing basis. The NRC staff makes a finding on the totality of the technical and safety basis put forth by the applicant or licensee.

2.2 NRC Code Development

Representative LWR regulatory areas where applicants and the NRC depend on modeling and simulation tools, computer codes, and computational analysis are shown in Figure 1. As shown in the figure, the functional areas where code development has occurred over the last several decades include reactor kinetics and criticality, fuel performance, thermal-fluid phenomena, severe accident phenomena, offsite consequence analysis, radiation protection and health physics, materials and component integrity, and probabilistic risk assessment. These areas are not necessarily all inclusive, and new areas may arise or be adjusted as the non-LWR designs become more specific and as NRC safety evaluations proceed.

The staff evaluates an application to determine whether compliance with the regulatory requirements has been demonstrated. Modeling and simulation tools used for NRC confirmatory analyses can be effective in helping the staff to evaluate the importance of various phenomena and the overall safety margins discussed in an application. Through its planning, the Office of Nuclear Regulatory Research has identified tasks and approaches to ensure the licensing organizations will have these capabilities not only at the initial licensing stage but for future regulatory applications involving a specific non-LWR design. Each volume provides an overview of the regulatory context for computational analyses.

Code development and maintenance has been a continual, on-going activity since NRC codes were first developed starting in the early 1970s. The continual needs for code development have been due to the evolving demands of the nuclear industry. Codes were initially designed to simulate design basis and severe accidents and their consequences, as well as to enable the staff to evaluate nuclear plant performance and safety significant systems. Improvements in these codes and their capabilities has been necessary to understand and approve license applications for the many reasons described including plant design changes that support improved operational economics. Additionally, the need to evaluate passive safety systems or unique features of new plant designs, to include non-LWR designs, has also driven the need for advancements in the analytical tools.

The staff expects there to be a continuing need for code development as industry demands evolve. In the next several years, the staff anticipates requests to evaluate the safety of new concepts including ATF and non-LWR designs. Effort is needed to modify and improve the NRC codes to efficiently simulate the impact of these concepts on nuclear plant performance and public safety in accordance with the regulatory requirements.

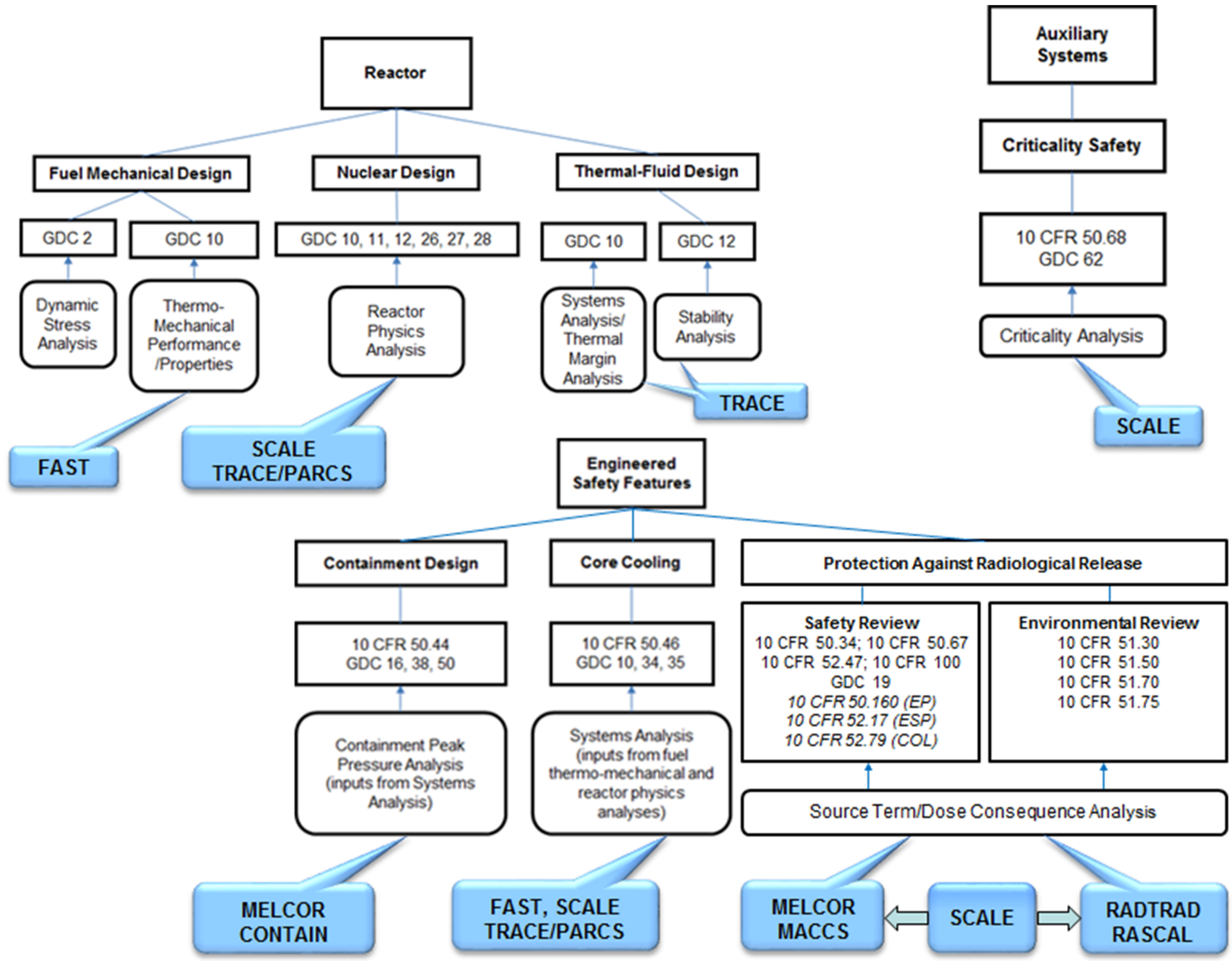

Figure 1. NRC Codes Used for LWR DBA and BDBA Analyses[1]

An important outcome of code development activities include the development of staff expertise and knowledge of the design and operation of new non-LWR types. Staff technical expertise is an essential element of an efficient and timely safety review of a particular new design or any future design modification. Staff attendance at training sessions on new technologies and designs along with vendor interactions are only one aspect of staff preparation and readiness to review license applications. Understanding the complex response of the plant to potential accidents requires a deep understanding of phenomenology and interaction between plant systems and components. Important and safety significant phenomena are captured in codes supported by experimental observations and data, but the boundary conditions (e.g., behavior of a valve) are equally important. Today, the easiest and perhaps the most efficient way to achieve this objective is through computer code development and simulations performed by staff. This

[1] Note that the figure references the general design criteria (GDC); staff expectation is that most non-LWR developers will use principal design criteria (PDC) more closely aligned with the advanced reactor design criteria (ARDC) referenced in Reg Guide 1.232, but that the general outline of the figure will remain applicable to those PDC used by designers.

approach has served NRC well over the past decades for LWR applications (both reactors and spent fuel pools) and continues to support the agency's risk-informed decision making as evidenced by recent staff studies (e.g., post 9/11 security assessments and disposition of Fukushima related recommendations). In some cases, the use of computer code simulations has reduced the need for independent confirmatory analysis because it has become easier for staff to review the licensee's code calculations in support of design changes and impacts on risk.

In making its code selection recommendations, many factors were considered including the need for the efficient use of resources, regulatory independence, and the development of staff expertise.

2.3 Efficient Use of Resources

While the staff considered codes developed by the NRC and external organization, such as by DOE, commercial companies, university and international organizations, its choice of codes is governed by the need to make the most efficient use of NRC resources. This includes consideration of the following factors in addition to others that are described in each of the Volumes:

- Existing staff familiarity with the use of NRC codes;
- Need for fewer modifications to existing codes;
- Level of code maturity and the use of correct physics and solution convergence;
- Ability to leverage externally funded code development programs;
- Use of codes with modern architecture to facilitate code interoperability, faster run times, and uncertainty analyses;
- Use of external codes to fill known gaps in NRC code models and validation; and
- Degree of code verification and validation.

It has been common place for LWR licensees, vendors and applicants to develop their own codes for the purposes of designing, licensing, constructing and operating their plants, while the NRC has developed its own codes to support a wide range of regulatory applications as described above. Representative NRC-developed codes include:

- Fuel performance codes like FRAPCON, FRAFTRAN, and Fuel Analysis under Steady-state and Transients (FAST);
- Neutronics codes like Purdue Advanced Reactor Core Simulator (PARCS) and Standardized Computer Analyses for Licensing Evaluation (SCALE);
- Thermal hydraulics systems codes like TRAC/RELAP Advanced Computational Engine (TRACE) and Symbolic Nuclear Analysis Package (SNAP);

- Source term, severe accident progression and offsite consequences codes such as MELCOR and MELCOR Accident Consequence Code System (MACCS); and,
- Radiation protection and health physics codes such as Radiological Assessment Systems for Consequence AnaLysis (RASCAL), RADionuclide Transport and Removal And Dose Estimation (RADTRAD), and NRCDose among others

In addition to NRC and domestic organizations, these codes have been used over decades by international organizations through various NRC code sharing programs for safety and regulatory analyses of LWRs; thus, the staff has an in-depth understanding of how the codes run and how to debug them. There is a significant level of staff understanding, knowledge and expertise related to the models, input parameters and data used to validate and run the NRC codes, and the cost to train new users is relatively small. Code modifications made over the many years also represent an embedded history of the NRC's performance of safety analyses for LWRs and have captured the staff's knowledge of the safety of reactor operations. Some of the NRC codes, like MELCOR, have been developed over many years to include non-LWR design features and phenomena that are important for safety analyses, and some existing capabilities for LWR analyses can be used for those purposes. Regarding the long-term maintenance of NRC codes, there is a cost and resource savings in using the same code for both LWR and non-LWR analyses because changes to the code architecture, such as for analytical code convergence, would be applicable for both LWR and non-LWR analyses.

More recently, NRC has been interested in leveraging the significant investment in DOE sponsored codes, such as the ones developed under the CASL and NEAMS programs, to fill known analytic and technical gaps and minimize NRC code development costs. The CASL and NEAMS programs have resulted in the development of advanced nuclear code analysis capability utilizing modern code architecture, an interoperable code structure, and scalable high performance computing systems. The benefits of using some of the DOE codes include faster code execution times, greater analytical flexibility, and the ability to solve complex problems involving fuel performance, reactor kinetics and accident progression sequences as a coupled suite of codes among others. Additionally, there has been a strong willingness and commitment of DOE and the National Laboratory personnel to provide the NRC with their codes and hands-on code development support at no cost to the NRC. Thus, a cost savings through the use of external codes, and in particular the NEAMS codes, can be achieved for non-LWR code development activities. Additionally, the utilization of staff resources to gain familiarity of non-NRC developed codes could hedge against uncertainties associated with the future funding of NRC code development activities.

For the reasons identified above, the NRC is recommending an approach to code selection that not only incorporates the use of historically NRC developed codes, but also includes the use of externally developed codes such as those from the DOE NEAMS program. More specifically, for traditional design basis analyses, the staff is recommending the use of a combination of NRC and DOE codes. For non-LWR source term development, severe accident evaluation and accident progression analyses, the NRC is recommending reliance on NRC developed codes for several reasons including the significant advancements made during the last decade to add non-LWR analysis capability to MELCOR and the fact that there are no DOE counterpart codes for BDBA analyses. Each of the Volumes describes in more detail the bases for the staff's selection of codes.

2.4 Regulatory Independence

One of NRC's five "Principles of Good Regulation" is Independence. Maintaining an independent capability to analyze reactor conditions during normal and off-normal conditions directly supports the NRC's ability to make objective, unbiased and well-founded regulatory decisions. In practice, maintaining an independent capability to analyze reactor conditions goes beyond the ability to use analytical tools to produce predictions for reactor conditions during normal, off-normal, accident and severe accident conditions. Regardless of which codes the NRC uses, the staff must have the ability to understand the assumptions and limitations of the analytical tools used by both the staff and those used by applicants and licensees. Staff understanding of the range of conditions for which the code have been validated and the nature of the validation database is critically important. Additionally, an understanding of the safety issues examined by the analytical tools and their sensitivity to various assumptions and uncertainties is equally important. This means that the staff must have the skills to understand the analytical regime of interest and the phenomena of safety significance.

Given the early stage of code development efforts for both the NRC and non-LWR developers, the staff may select codes that are completely different than those selected by future applicants, as has been typical for the LWR industry. Alternatively, the staff and developers may choose to use some of the same codes. Even if the codes are exactly the same and yield the same results, the NRC can maintain its independence because of the substantial technical expertise and experience of the NRC staff in addition to its access to world renowned experts who could help evaluate the results. This is because the analytical tools form only one element of the demonstration of the safety case and the NRC review evaluates the broader scope of the design. As the developers plans evolve, the NRC will evaluate each situation to determine what is required for an independent analysis capability.

It is important to note that while the NRC staff is developing its plans for confirmatory analysis codes and tools, the non-LWR developers are in the best position to decide which codes they want to use to support the design and future licensing activities of their technologies. That is, it's the developer's responsibility to select their own reactor safety and analysis codes which will then become one important element of their future licensing bases.

2.5 Prioritization of Resources

The staff's plans, as represented in the accompanying Volumes of this report, characterize code development activities based on what is currently known about the non-LWR developers' plans for formal regulatory engagements, including plans for licensing submittals, and less formal interactions with the NRC. The staff's intent was to document as many of the code development activities as is possible given the state of knowledge about the different non-LWR designs. For some designs, such as SFRs and GCRs, there is significantly more design and phenomenological information and experimental data available such that the staff can build "reference plant" designs which are similar in nature to previously designed and operated reactor types. For these designs, the staff's code development plans and associated tasks are relatively complete. However, for other designs, such as molten salt reactors, there is sufficiently large variability in the designs and regulatory engagement plans that code development plans are less complete and will need to be updated as the MSR technologies evolve and mature. Information about the staff's code development plans for heat pipe designed "micro" reactors are also included based on as much information as is available to the staff at the present time. Overall, the staff believes that the plans and tasks, as described in each of the Volumes, are as complete as can be at this time.

In FY17, the NRC started receiving off-fee based funding to support a broad range of strategies, including code development activities, to prepare the agency for licensing of non-LWR designs. From a contract funding perspective, the NRC's code development activities have been modest in part due to uncertainty in the priorities of the non-LWR industry for licensing the wide range of technologies being proposed. Most of these resources were spent on:

- Conducting gap analyses to determine where to focus fuel performance, DBA, BDBA, accident progression, incident response, and materials and component integrity code development resources;
- Working closely with DOE and the National Laboratories to identify and evaluate the capabilities of the CASL and NEAMS codes for potential use in NRC's fuel performance and DBA analyses;
- Staff participation in DOE training for some of the NEAMS codes;
- Initiation of preliminary fuel performance and accident progression code development activities as well as the developing neutron cross section and material property libraries;
- Developing databases of non-LWR materials and component integrity operational experience and potential MSR degradation mechanisms and phenomena along with identifying potential code development tools; and
- Developing the detailed code development plans that are described in Volumes 1 through 3 of this report.

A summary of the staff's FY18 accomplishments can be found in the FY18 "Strategy 2" status report [9] in addition to the FY18 Annual Commission paper [10]. As additional funding is made available, discrete milestones for completing the tasks described in each of the Volumes will be identified.

As further funding decisions occur, the staff will need to be conscientious and deliberate about which tasks receive funding since not all tasks can be funded in a given year and code development plans will evolve in response to changes associated with the various non-LWR technologies. Accordingly, the staff's code development plans are comprised of approaches and tasks utilizing the considerations below. Generally, funding prioritization will be considered at the code development task level and higher priority will be given to:

- Code development activities that support flexibility for use with a wide variety of reactor technologies;
- Code development activities that are nearly completed, such as change to code architecture initiated for LWR applications but applicable to non-LWR applications;
- Tasks that help identify long lead time data needs, such as for a specific type of non-LWR technology (e.g., molten salt chemistry) and have relatively more certainty relative to the timing of the submittal of an application;
- The capacity of NRC contractors to complete activities. With few experts in a field, such as for MSR, there may not be enough conflict free expertise to support concurrent NRC and industry code development needs;
- Task completion dependencies (e.g., source terms are needed before modifications to codes used for siting analyses can be made);
- Code development activities that support the staff's understanding of potential applicant's codes and analytical tools; and,
- Data acquisition activities that supports code development for multiple reactor designs.

Overall, the staff will make code development and modelling progress and will need to change priorities as funding is made available and as the needs and priorities of the non-LWR industry become clearer.

2.6 Predictive Code Capability

The NRC has historically used codes for the evaluation of new designs and associated accident scenarios of interest. The goal of doing so is to ensure that the outcome of a particular analysis shows the applicant's results are acceptable and there is safety margin relative to the design and operating conditions for a particular reactor design. The NRC has not been in the practice of using codes in a predictive manner outside the bounds of where there is data available to confirm the anticipated behavior of the reactor under a wide variety of conditions. More specifically, for DBA and BDBA analyses, NRC codes have been historically used where the phenomena of importance are identified and modelled; key data are obtained from experiments to validate the response of the fuel, reactor and safety systems to potential accidents and upset conditions; and safety margins and uncertainties are quantified within the bounds of anticipated phenomena and accident response. Both DBE and BDBE codes used for LWR analyses are based on semi-empirical models and correlations validated available test data. Neither DBE nor BDBE codes have the benefit of full-scale test data. Thus, validation is based on relatively small scale experiments and the codes are extrapolated in scale to the full sized plant design. DBE codes have a larger database, because that data is easier to obtain than severe accident data where the phenomena involves core degradation and radionuclides release and transport.

So, in both cases the codes are validated to the extent possible using applicable data. Unless there is a compelling reason why the NRC should change its approach to safety assessment, the NRC will continue to perform its regulatory analyses using codes that are validated using applicable sets of data for DBA and BDBA analyses. The NRC staff will continue to carefully evaluate the existing and available data and account for uncertainties by performing sensitivity studies and/or bounding some phenomena if there is a lack of data.

2.7 Code Validation

The NRC has always placed great importance in computer code accuracy and quantification of uncertainties for accident scenarios involved in plant licensing. Regulatory Guide 1.203 summarizes the general approach that is expected by the staff in the development of evaluation models for safety analysis. In the current budget constrained environment, the staff's approach to completing code validation and assessment will rely heavily on data sources from international organizations, DOE, and the vendors who submit regulatory applications. For example, one key assumption regarding the NRC's use of the NEAMS codes is that DOE will conduct validation exercises using existing experimental data. The staff will continue to work closely with DOE and the vendors to communicate its needs for additional experimental data and other analytical information to support its code development activities.

3.0 STAKEHOLDER INTERACTIONS

The staff is closely following ongoing non-LWR developers' plans and the evolution of design details for the variety of non-LWR technologies. The staff is also working closely with DOE and the National Laboratories on development and assessment of the NEAMS suite of codes. The staff has also continued to engage with developers of the CASL codes and remain cognizant of the capabilities of those codes. Frequent communications with these stakeholders through the periodic Advanced Reactor Stakeholder meetings and many other technical meetings has provided the staff with many opportunities to seek input on the status of non-LWR design development, identification of analytical capabilities, a better understanding of the phenomena important to safety that will need to be included in NRC's analytical tools and input regarding NRC's selection of codes to support future non-LWR licensing activities.

The staff plans to more actively engage with the industry through Technology Working Group meetings, National Laboratory led topical workshops and other venues to communicate our approach and plans for non-LWR code development activities, identify opportunities for the staff to obtain experimental data that will help with code validation, and obtain feedback on our code development plans. Additionally, in developing this plan, the staff believed it is prudent to solicit external stakeholder feedback on a few topics to inform future decisions. As such, in addition to providing the NRC with comments on the overall approach in these reports, the NRC is interested in feedback on the following items:

- IAP Strategy 2 was initially developed roughly three years ago. Does this Strategy still reflect the best course of action for the NRC to develop sufficient expertise and readiness for conducting non-LWR reviews? If so, why? If not, what changes to the Strategy should be considered?

- As an alternative to Strategy 2, should the NRC consider an approach wherein NRC access to developer and applicant codes is provided, and NRC staff could conduct confirmatory or sensitivity analyses using those codes rather the approach proposed in this report? What are the pros and cons to this alternative approach?
- Some applicants may develop their licensing bases events following the approach of the Licensing Modernization Project (LMP). The LMP approach to licensing basis events and associated acceptance criteria (e.g., dose consequences) is fundamentally different than historical methods for establishing licensing basis events and associated acceptance criteria (e.g., fuel design limits). What then should the role of the codes discussed in Volume 1 be under an LMP approach?

4.0 ADDITIONAL CODE DEVELOPMENT ACTIVITIES

Volumes 1 through 3 describe the codes the staff is recommending be used, modified and further developed for fuel performance, DBA and BDBA analyses. Additional volumes may be developed to address the needs for codes and analytical tools not described in Volumes 1 through 3 as the priorities and associated funding support. For example, under development is Volume 4, which describes the codes the staff is recommending be used to support dose assessments for initial licensing and National Environmental Policy Act siting reviews, emergency response and other health physics calculations unique to the non-LWR technologies.

Other potential code development needs include those in the areas of Probabilistic Risk Assessment (PRA), materials and component integrity analyses, and fuel manufacturing, storage and transportation. More specifically, while existing PRA codes used by the NRC are technology inclusive, they may need to be modified, or other PRA tools may need to be developed, to support NRC's independent review of the risk-informed approaches that are being developed and considered by prospective non-LWR applicants. Also, proposed non-LWR designs will require some materials exposed to unique environmental and loading conditions such as operation at higher temperatures than conventional LWRs. The staff is currently in the process of endorsing the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 5, which include design rules for construction and operation of non-LWR components. In parallel, the staff has been identifying analytical gaps and may develop computational tools to confirm the application of design rules for chosen materials used in potential design application. A separate volume on the staff's development plans for analytical tools to support assessments of materials and component integrity issues may be developed. Additionally, the staff is also considering what code development activities may be needed to support safety reviews associated with fresh and spent fuel transportation and storage.

5.0 REFERENCES

1. U.S. Nuclear Regulatory Commission, "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," December 2016, Agencywide Document Access and Management System (ADAMS) Accession No. ML16356A670.

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