U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

PROJECT PLAN TO PREPARE THE U.S. NUCLEAR REGULATORY COMMISSION FOR EFFICIENT AND EFFECTIVE LICENSING OF ACCIDENT TOLERANT FUELS

Version 1.2

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1 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is committed to enabling the safe use of new technologies, especially those that can increase the safety of NRC -regulated facilities. The U.S. nuclear industry, with the assistance of the U.S. Department of Energy (DOE), plans to deploy batch loads[1] of certain accident tolerant fuel (ATF) concepts, fuels with higher burnup levels, and fuels with enrichment above the current 5 weight percent uranium-235 in the operating fleet on an aggressive timeline (by the mid-2020s). The NRC is optimistic that its preparation strategy and new paradigm of fuel licensing outlined in this Project Plan will support that schedule while still providing reasonable assurance of public health and safety at U.S. nuclear facilities and installations. The NRC understands that it may face challenges in its preparations and technical and licensing reviews, but it is committed to working through such challenges in a thoughtful and deliberative manner.

In an attempt to increase regulatory stability and certainty, enhance and optimizing NRC review, and reduce the likelihood of not meeting the requested schedules (i.e., schedule risk), the staff has developed this plan, which includes a vision for a new paradigm for the licensing of ATF, higher burnup, and increased enrichment. The staff believes that adherence to this strategy will benefit all the agency's stakeholders in the planned deployment of ATF designs, higher burnup, and increased enrichment.

The NRC staff has extensively engaged with its stakeholders in the development and finalization of each version of the Project Plan, consistent with the NRC's principles of good regulation and statutory requirements. The staff has held one public meeting with external stakeholders, including licensees, nuclear fuel vendors, industry groups, nongovernmental organizations, and international counterparts for Version 1.2 and the meeting summary can be found in the Agencywide Document Access and Management System (ADAMS) at Accession Nos. MLxxxxxxxxx. The staff found this interaction and the previous interactions for ATF Project Plan Versions 1.0 and 1.1 (ADAMS Accession Nos. ML18261A414 and ML19301B166, respectively) invaluable, and has considered the views and comments of the NRC's stakeholders in finalizing this Version 1.2 of the ATF Project Plan.

The Project Plan presents the high-level strategy that the staff will follow to ensure that it is ready to review ATF, higher burnup, and increased enrichment topical reports (TRs) and/or licensing actions for the entire nuclear fuel cycle within the schedules requested by the industry. At this point, the strategy is concept and technology independent. ATF "concepts" are defined as a family of ATF designs developed by vendors with largely similar characteristics. Examples include coated zirconium (Zr) alloy claddings, steel claddings, silicon carbide (SiC) claddings, or metallic fuels. Individual vendors may implement variations within each concept as specific technologies.

[1] A batch reload is defined as the typical number of fuel assemblies that are replaced in the reactor core after each operating cycle; this is generally around one-third of the total fuel assemblies in the core.

2 BACKGROUND

In a coordinated effort under the direction of the NRC's ATF steering committee, the Office of Nuclear Reactor Regulation (NRR), Office of Nuclear Material Safety and Safeguards (NMSS), and Office of Nuclear Regulatory Research (RES) are preparing for the licensing, fabrication or production and use of ATF, higher burnup, and increased enrichment in U.S. commercial power reactors.

In coordination with DOE, several fuel vendors have announced plans to develop and seek approval for various fuel designs with enhanced accident tolerance (i.e., fuels with longer coping times during loss of cooling conditions), higher burnup, and increased enrichment. The concepts considered in the development of this plan, both within and outside of the DOE program, include coated claddings, doped uranium dioxide (UO_2) pellets, iron-chrome-aluminum-based (FeCrAl) cladding, SiC cladding, uranium nitride (UN) pellets (replaced the previously under-development uranium silicide (U_3Si_2) pellets), and metallic fuels (e.g., Lightbridge).

Based on stakeholder interactions, the NRC staff is aware of industry's plans to request higher fuel burnup limits along with the deployment of near-term ATF concepts because it provides an economic balance to the increased cost of ATF. The staff expects an increase of fuel burnup limits up to approximately 75 gigawatt days per metric ton of uranium (GWd/MTU) rod-average (or equivalent). To achieve those burnups, the industry will need to requests increases in fuel enrichment from the current standard of 5 weight percent uranium-235 up to approximately 10 weight percent uranium-235, which the industry has labeled as low enriched uranium plus (LEU+)[2]. Additionally, on January 14, 2019, the President signed the Nuclear Energy Innovation and Modernization Act (NEIMA). NEIMA, Section 107, "Commission Report On Accident Tolerant Fuel," provides a definition of ATF as a new technology that: (1) makes an existing commercial nuclear reactor more resistant to a nuclear incident; and (2) *lowers the cost of electricity over the licensed lifetime of an existing commercial nuclear reactor*. Due to this economic link between higher burnup, increased enrichment, ATF technologies, and the NEIMA definition, pursuit of higher burnup and increased enrichment is considered a component of the ATF program.

This Project Plan covers the complete fuel cycle, including consideration for the front-end (i.e., enrichment, fuel fabrication, fresh fuel transportation) and back-end (i.e., spent fuel transportation and storage), and outlines the strategy for preparing the NRC to license ATF designs, higher burnup, and increased enrichment. It also identifies the lead organization for each planned activity. This plan only briefly touches on existing licensing activities, such as the

[2] LEU+ is a term used by industry to describe the enrichment levels that the ATF near term concepts will be enriched to. Another term used by industry and DOE is the term high assay low enriched uranium (HALEU) which they define as fuel enriched from 5 weight percent uranium-235 and less than 20 weight percent uranium-235. Both of these industry terms fall under NRC regulatory definition of LEU defined in 10 CFR 50.2 as fuel in which the weight percent of U-235 in the uranium is less than 20%.

TR process, the implementation of lead test assembly (LTA) programs, the license amendment request (LAR) process, and front-end and back-end licensing actions, as such activities follow existing processes that have well-established schedules and regulatory approaches or are being clarified through NRC initiatives outside of the ATF Steering Committee and Working Group.

In preparing the agency to conduct complete and timely reviews of these new fuel designs, the NRC is reviewing the existing regulatory infrastructure and identifying needs for additional analysis capabilities. The NRC has entered a memorandum of understanding (MOU) with DOE to coordinate on the nuclear safety research of ATFs that will make the appropriate data available for regulatory decision-making processes. In addition, the NRC has established an MOU with the Electric Power Research Institute (EPRI) to facilitate data sharing and coordination on expert elicitation.

For the purpose of developing this plan, ATF concepts are broadly categorized as near-term and longer term. The plan considers near-term ATF concepts as those for which the agency can largely rely on existing data, models, and methods for its safety evaluations (SEs). Coated cladding, FeCrAl cladding, and doped UO_2 pellets are the current near-term ATF concepts. The industry is pursuing coated cladding and doped pellets for deployment by the mid-2020s; however, licensing or deployment dates for FeCrAl have not been provided to the NRC at this time. Longer-term ATF concepts are those for which substantial new data, models, and methods need to be acquired or developed to support the agency's SEs. UN fuel, metallic fuel, and SiC-based cladding are the current longer-term ATF concepts. "Near-term" and "longer term" are often terms of convenience used to indicate the current expected deployment timeframe for the ATF concept. Potential licensing and deployment dates for the longer-term technologies have not been provided to the NRC at this time.

Regulatory requirements do not vary between near-term and longer-term concepts, and the NRC will evaluate all designs based on their individual technical basis. The timeline for licensing will be commensurate with the deviation of the ATF technology from the current state of practice and the number and complexity of issues related to phenomena identified during an expert elicitation process (e.g., a phenomena identification and ranking table (PIRT) exercise). The agency is focusing its current ATF licensing preparation on the use of ATF in light-water reactors (LWRs) in the operating fleet. Some overlap may occur between LWR ATF fuel development and fuel safety qualification of some types of non-LWR fuels for advanced reactor designs. As appropriate, the NRC will leverage previous experience to help optimize licensing efficiency and effectiveness, and reduce schedule risk

This Project Plan will be a living document that may evolve as (1) ATF concepts, higher burnup, and increased enrichment are more clearly defined, (2) schedules are refined, (3) the knowledge level of specific concepts increases as experimental testing programs are completed, and (4) potential extensions to the current operating envelope of fuel are identified.

2.1 NRC Staff Organization

The NRC's ATF, higher burnup, and increased enrichment activities are led by the ATF Steering Committee, which is made up of the executives who lead the technical and licensing divisions involved with ATF. The ATF Steering Committee is headed by the Director of the Division of Safety Systems in NRR.

Figure 2.1 The NRC's ATF Steering Committee

ATF Steering Committee		
Office of Nuclear Reactor Regulation	**Office of Nuclear Regulatory Research**	**Office of Nuclear Material Safety and Safeguards**
• Division of Safety Systems (*chair*) • Division of Operating Reactor Licensing	• Division of Systems Analysis	• Division of Fuel Management • Division of Rulemaking, Environmental, and Financial Support

Additionally, the working-level ATF Working Group consistently contains staff members from:

Figure 2.2 The NRC's ATF Working Group

ATF Working Group		
Office of Nuclear Reactor Regulation	**Office of Nuclear Regulatory Research**	**Office of Nuclear Material Safety and Safeguards**
• Division of Safety Systems • Division of Operating Reactor Licensing • Division of Risk Assessment	• Division of Systems Analysis • Division of Risk Assessment	• Division of Fuel Management • Division of Rulemaking, Environmental, and Financial Support

Staff from many other Divisions and NRC Offices, have become involved in Steering Committee meetings and Working Group activities because ATF, higher burnup, and increased enrichment touches almost every aspect of the nuclear fuel cycle. The work necessary to prepare for ATF, higher burnup, and increased enrichment is truly an agencywide effort that requires coordination and support from multiple technical, projects, administrative, and legal organizations within the NRC.

2.2 ATF Workload Management and Staff Skillsets

The majority of the staff efforts for ATF will be performed by the members of the divisions involved in the ATF Working Group; however, many different organizations can be involved with

ATF-related activities on limited bases. Staff from these other organizations, such as OGC and the NMSS rulemaking branch, may be requested to fulfill roles when needed. To ensure appropriate participation and effort, managers of the requested staff must approve of their ATF-related roles and assignments.

When it is determined that necessary skillsets are not available within the current staff, the NRC will put forth the effort to develop staff and contractors with critical skills required to support projected applications of high to moderate certainty.

3 ACCIDENT TOLERANT FUEL LICENSING PROCESS

This Project Plan focuses on the NRC's preparations to conduct efficient and effective reviews for ATF designs, higher burnup, and increased enrichment on a schedule consistent with industry-requested timelines. Many different types of NRC reviews are necessary before ATF, higher burnup, and increased enrichment can be adopted by industry.

TRs provide the generic safety basis for a fuel design and do not, by themselves, grant approval for operating plants to begin loading ATF, higher burnup, or increased enrichment. These reviews for new fuel designs have historically taken between two and three years to complete. Based on past experience, vendors should also anticipate that the NRC's Advisory Committee on Reactor Safeguards may request to review TRs and should include time for such reviews in their planning and schedules.

In addition, a licensee may need to submit a plant-specific LAR to modify its license to allow for the use of an ATF design, higher burnup, or increased enrichment. LARs address all plant-specific aspects of implementing an ATF design. Traditionally, new fuel design LARs are typically completed on a 18-month review schedule; however, the length of time required to review a new ATF design, higher burnup, and/or increased enrichment LAR is heavily dependent on many factors, including the amount of licensing credit requested by the licensee, number of components of the request (e.g., just an ATF design, an ATF design combined with higher burnup, or an ATF design combined with higher burnup and increased enrichment), and other relevant submittal information. Approximate LAR review timelines can only be provided to industry when applications are received and an acceptance review is performed to determine the scope of the review. Upon final approval of the plant-specific LAR, a licensee would be authorized to load and irradiate batch quantities of the specific ATF design, higher burnup, and increased enrichment in accordance with its license.

In addition to power reactor TRs and LARs, there are many necessary materials-related licensing actions for both the front-end and back-end of the fuel cycle both before and after batch loading of ATF, higher burnup, and increased enrichment into power reactors. Some examples of these actions are enrichment facility license amendments to increased allowed enrichment levels, fuel fabrication facility licensing to manufacture new fuel designs, changes to transportation package and dry cask certificates of compliance, and changes to specific licenses for independent spent fuel storage installations. Many of the front-end licensing actions need to be completed in advance of insertion of fuel with ATF designs, higher burnup, and/or increased enrichment. The utilization of ATF, higher burnup, and/or increased enrichment would not be possible without these vital materials-related licensing actions.

3.1 Assumptions

Given the current uncertainty related to the development and deployment of ATF concepts, the NRC staff made the following major assumptions to help in its development of this plan:

- The NRC will not need to perform independent confirmatory testing for specific ATF designs, higher burnup, or increased enrichment. The NRC expects that the applicant, DOE, international multi-party research projects, or other organizations will provide the agency with all data needed to support the safety basis for a concept. Additionally, the NRC expects that all reactor and test-generated fuel behavior data will be provided to the agency in a timely manner so that it can assess NRC analysis capabilities. If NRC-performed confirmatory testing is necessary due to a large safety significance and uncertainty, then the timelines detailed in this Project Plan are no longer applicable.
- Interaction with DOE, EPRI, vendors, and other organizations involved in ATF-related experimental programs will take place in real-time and, whenever possible, in advance of experiments being conducted.
- The NRC’s interactions with external stakeholders will keep the staff and stakeholders informed about both technical and programmatic developments that are affecting activities identified in this Project Plan.

3.2 Project Plan Paradigm

This Project Plan envisions an improved fuel licensing paradigm, depicted in Figure 3.1, that can increase the efficiency, increase the effectiveness, and reduce schedule risk of the NRC’s review of ATF designs, higher burnup, and increased enrichment.

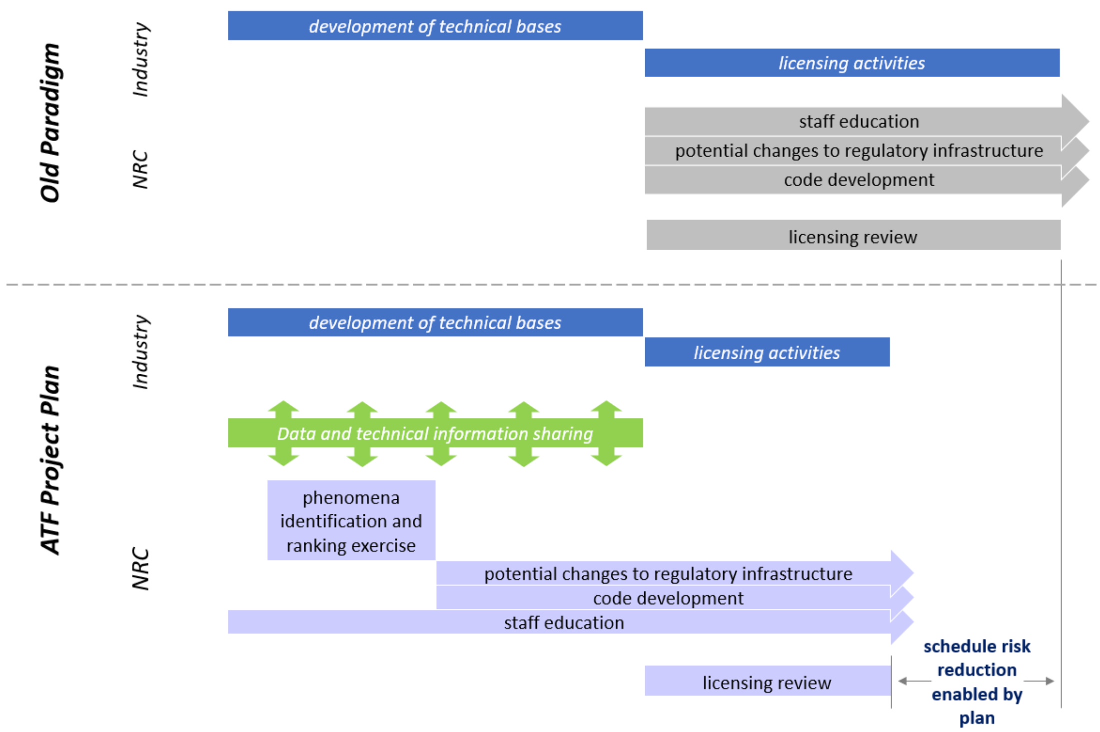

Figure 3.1 ATF Project Plan new paradigm

3.2.1 Old Paradigm

In the old paradigm, the NRC is reactionary to the nuclear industry's activities. The NRC would often find out about a new technology only when a vendor or licensee submits a licensing action or requests a presubmittal meeting close to the submittal date. At this time, the NRC staff would start three activities:

- educating themselves on the technologies through research and discussion with the applicant.
- assessing potential changes to the regulatory infrastructure once they have a sufficient amount of information from the submittal or presubmittal meeting.
- developing the fuels analysis codes and models to ensure that independent confirmatory calculations are available for licensing needs.

This education, changes to regulatory infrastructure, and code and model development are started after the development of the technical bases for the new technology. Additionally, the lack of guidance and information exchange can result in a mismatch between submittals and NRC staff expectations, possibly resulting in resource intensive requests for additional information (RAIs) and extending the time necessary to resolve technical and/or regulatory issues. Both of these challenges can result in significant risk to the review schedule.

3.2.2 New Paradigm

Industry's pursuit of ATF, increased enrichment, and higher burnup has led the staff to reflect on the NRC's fuel licensing process and determine where improvements can be accomplished and where schedule risk can be reduced. The goal of this new paradigm is to enhance regulatory stability and reduce risk to the timeline required for licensing activities following the completion of the technical basis to support an ATF design, higher burnup, or increased enrichment.

As illustrated in Figure 3.1, the Project Plan encourages data and information sharing with NRC staff in parallel with the development of the technical basis for new technologies. The data sharing and early NRC staff engagement with the vendor during this time will be critical in reducing the schedule risk. In addition to the information sharing, the staff can begin familiarizing themselves with, and gathering information on, the technology at a much earlier stage. If appropriate, the NRC may also conduct a PIRT exercise for each ATF concept when necessary, as explained in Section 3.2.3 below. Based on the outcome of the PIRT process or other preparatory activities, staff may opt to make changes to the regulatory infrastructure as needed. Any changes to the regulatory infrastructure will involve significant communication with agency stakeholders to maintain transparency and clearly communicate regulatory expectations to the vendors. The staff also will begin preparing agency codes to minimize any lead time needed for performing confirmatory calculations after applications are received.

The success of the new paradigm is contingent on the early industry engagement and voluntary sharing of information with the NRC. Without these two key activities, the licensing process will have to proceed under the old paradigm, resulting in greater schedule risk.

3.2.3 Phenomena Identification and Ranking Table Exercises

As stated above, the success of the strategy outlined in the Project Plan has the staff conduct thorough and meaningful PIRT exercises for each concept and maintain the results of the PIRT as the collective state of knowledge for each concept is advanced. For the purpose of this Project Plan, the term PIRT is defined as an expert elicitation process in which panelists will identify and rank new phenomena important to safety introduced by an ATF concept, higher burnup, or increased enrichment. The staff foresees that these exercises will vary greatly in scope and depth based on the departure of the concept from the current state of practice and the maturity of the concept. Some examples of potential exercises include independent NRC review of an industry generated failure mode analysis, a coordinated NRC and vendor exercise on a vendor-specific concept, and a multi-day PIRT panel with topical experts similar to previous NRC PIRTs such as on high-temperature gas reactors.

The experts selected for the PIRT panel should consider the full intended use of the concept to ensure that the PIRT results are meaningful even if initial licensing applications do not intend to seek credit for the enhanced capabilities of the concept. A lack of consideration of the full operating envelope in the initial PIRT exercise could lead to uncertainty further along in the process when a vendor or licensee does seek to credit those capabilities.

The NRC staff relies on the agency's significant expertise in the Zr-clad UO_2 fuel system during the review of current fuel licensing submittals. However, the staff does not necessarily have this same level of knowledge for all the ATF concepts, higher burnup, or increased enrichment that industry is currently pursuing. The NRC staff is monitoring the literature and experimental testing programs conducted in the public domain and is participating in industry and DOE update meetings on ATF concept development. However, more in-depth expertise may be needed to support the efficient and effective review of ATF, higher burnup, and increased enrichment licensing submittals. PIRT exercises will allow the staff to benefit from external expertise to identify phenomenon important to safety for each concept and, therefore, to refine the regulatory framework that is necessary for a concept ahead of licensing submittals and that will serve as baseline guidance for the NRC's technical review.

In addition to concept-specific PIRTs, discipline-specific PIRTs may be useful in some cases. Examples considered to date include PIRTs in the areas of severe accidents, storage and transportation, burnup above 62 GWd/MTU rod-average (or equivalent) and enrichment above 5 weight percent. The experts necessary to identify and evaluate new phenomena important to safety in these areas should be the same or similar experts for all or many of the ATF concepts, higher burnup, and increased enrichment under development. Therefore, the NRC staff believes that it would be more efficient to conduct these PIRTs in a discipline-specific manner instead of as part of the concept-specific exercises.

The NRC completed the first ATF PIRT exercise on Cr-coated cladding in June 2019. The PIRT began by collecting publicly available data on coated cladding concepts and producing an initial literature review, which was completed in January 2019 (ADAMS Accession No. ML19036A716). This literature review was used as background material for the experts who participated in the panel discussion and provided input to the final report (ADAMS Accession No. ML19172A154). This followed the schedule in the first version of the Project Plan.

Experts participating in the panel had background from academia, national labs, the nuclear industry and high temperature coatings. A multi-day public meeting was held where the experts discussed the initial report and their areas of expertise. After rating a list of fuel damage mechanisms by importance and level of knowledge the report was finalized.

This final PIRT report was then used to inform the development of interim staff guidance (ISG) on coated cladding. This guidance will be used to inform NRC staff reviews of coated cladding TRs and will ultimately be incorporated into NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition", otherwise known as the Standard Review Plan (SRP).

While the ISG was produced on an expedited timeline to facilitate issuance prior to the anticipated topical report submittals on coated cladding, the NRC staff have made efforts to include stakeholders in the process. This effort included opening the PIRT up as a public meeting, holding multiple public meetings on the ISG, and noticing the ISG in the *Federal*

Register for public comment. The ISG was issued on January 3, 2020 (ADAMS Accession No. ML19343A121).

The NRC completed a second PIRT exercise which covered the performance in severe reactor accidents of the current ATF concepts, higher burnup fuel, and fuel with enrichment above 5%. It also assessed the impact of ATF, higher burnup, and increased enrichment on accident source terms. The PIRT exercise took place from September 2020 through April 2021 and was led by NRC contractors at Energy Research Inc. The final report was completed in April 2021 (ADAMS Accession No. ML21113A277).

The NRC will develop timelines for subsequent ATF PIRT exercises and additional implementation details through coordination with its external stakeholders.

3.2.4 Effectiveness of the New Paradigm

The new paradigm for fuels licensing is a concept designed to increase efficiency and reduce schedule risk for NRC staff reviews of ATF, higher burnup, and increased enrichment licensing actions. It does not define the NRC's capability to review applications; the completion of the actions of the new paradigm (and the Project Plan as a whole) are not a "go" or "no go" measure determining if ATF technologies can be licensed today. The current licensing and regulatory framework continues to be applicable to near-term ATF, higher burnup, and increased enrichment without the activities promoted by the new paradigm. However, without these activities, there is increased schedule risk.

3.2.4.1 New Paradigm Effects on In-Reactor Topical Reports

The determining factor on whether the TR reviews can be completed on the industry's requested expedited timelines is driven largely by the quality and completeness of the submittals, including the information and technical data received from all sources. ATF uses technologies that are being licensed for the first time; higher burnup and increased enrichment are not new technologies but go beyond previous limits. It takes time for the staff to become familiar with new technical issues and the challenges that these bring, and to incorporate the data into confirmatory codes. As seen in Figure 3.3, the more technical data and knowledge the staff has received before and with a submittal, the better prepared the NRC staff will be to perform an efficient review with less schedule risk. The early information and technical data necessary to achieve fewer RAIs and conditions on use will vary with each ATF concept, higher burnup, and increased enrichment. For example, coated cladding and doped pellets have a minimal departure from currently licensed fuel; therefore, a large portion of the information and data necessary to make a safety determination is available and understood by the technical staff. In contrast, information and data for higher burnup and increased enrichment is not as available; therefore, more is needed to make a safety finding.

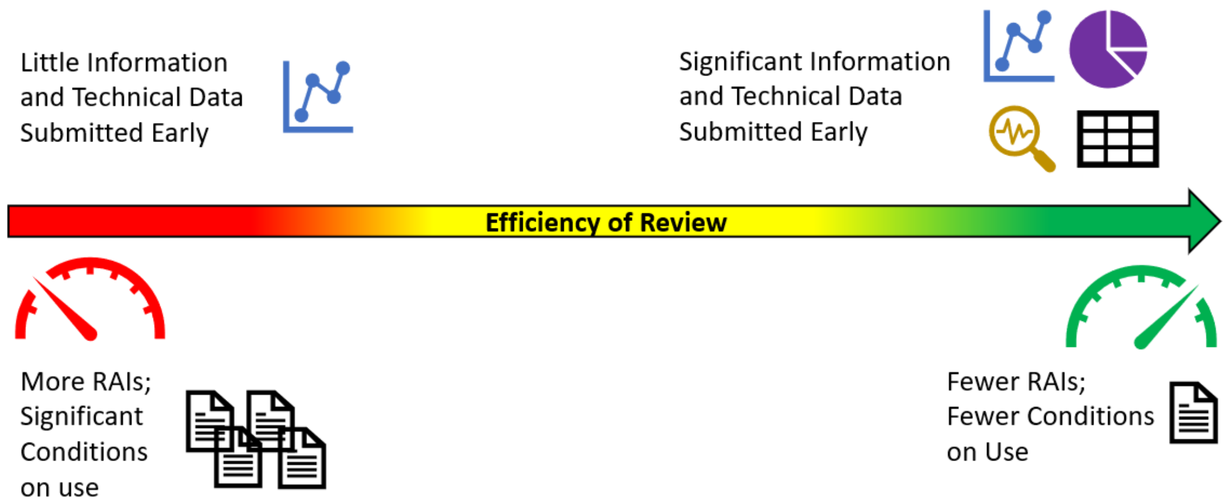

Figure 3.3 Data and Information vs. New Paradigm Efficiency

Additionally, communication with the applicants regarding their schedules is important to allow for the timely adjustment of staff resources for regulatory infrastructure changes (if any) and forthcoming submittals. Topical report project managers will encourage vendors to discuss their plans early and often regarding planned topical reports, including pre-submittal meetings.

Finally, the NRC needs to receive high quality[3] submittals to meet the requested timelines. The increased communications and pre-application efforts will not be successful if applicants do not provide a complete and data-supported application.

As the NRC does not plan to collect its own technical data, there is an expectation that sufficient data to support the safety basis for an ATF concept will either be submitted with the licensing application or will be available in public literature or from other stakeholders.

3.2.4.2 New Paradigm Effects on In-Reactor License Amendment Requests

Many of the aspects of the new paradigm translate into efficiencies for in-reactor LARs. Similar to the concept in Figure 3.3 for TRs, the more information the NRC has regarding a licensee's plans for in-reactor use, the more likely it will be that the NRC can meet the requested date for issuance of an amendment. Licensing project managers in the Division of Operating Reactor Licensing in NRR will encourage licensees to discuss their plans early and often regarding planned LARs, including pre-submittal meetings.

[3] "High quality" consists of, among other things, quantities of data and detailed discussions sufficient to thoroughly support the assertions made in the submittal. Applications that do not adequately support the contained assertions often result in requests for information and extended review timelines because the staff is not initially able to make a safety determination without additional review steps.

It is likely that licensees will be using varied approaches to license ATF, higher burnup, and increased enrichment for their facilities; therefore, the technical data needed by NRC staff to review ATF LARs is closely tied to the specific licensing approaches. For example, a licensing approach reliant on the performance of current fuel without taking additional credit for ATF safety improvements may require less data than one that takes significant credit for those improvements. For this reason, a defined set of required application contents could be unnecessarily prescriptive and inhibit flexibility by the applicant and the NRC.

The NRC staff is currently reviewing the regulations and guidance to identify the extent of their applicability to in-reactor LARs on coated cladding, doped pellets, higher burnup, and increased enrichment. A table of this applicability assessment can be found in Appendix A of this Project Plan and is discussed further in Section 7.1 of this plan. This list includes items that are not reviewed for most fuel-material TRs, such as dose assessments and environmental reviews. The identification of a regulation or guidance that is not fully applicable does not mean that ATF, higher burnup, and increased enrichment LARs cannot be reviewed today; there are regulatory strategies that can be used to proceed forward in the review (e.g., sensitivity studies to ascertain the importance of parameters on predicting pertinent phenomena). However, schedule risk may be higher until such regulations or guidance are made fully applicable.

3.2.4.3 New Paradigm Effects on Front-end and Back-end Licensing Actions

As with in-reactor LARs, many of the aspects of the new paradigm translate into efficiencies for fuel cycle front-end and back-end licensing actions. The more technical data and knowledge the staff has received before and on day one of a review, the more prepared the NRC will be and the lower the risk that the review will not meet the requested expedited timeline due to unforeseen technical or regulatory issues. The NMSS project managers will encourage their licensees and certificate holders to discuss their plans early and often, including pre-submittal meetings.

The NRC staff is currently reviewing the regulations and guidance to identify the extent of their applicability to front-end and back-end licensing actions on coated cladding, doped pellets, FeCrAl cladding, higher burnup, and increased enrichment can be found in Appendix A of this Project Plan and is discussed further in Section 7.1 of this plan. The identification of a regulation or guidance that is not fully applicable does not mean that ATF, higher burnup, and increased enrichment front-end and back-end licensing actions cannot be reviewed today; however, schedule risk will be higher until such regulations or guidance are made fully applicable.

3.2.5 Lessons Learned within the New Paradigm

Below are some broad lessons learned from experiences in the new paradigm with LTAs, TRs, and other licensing actions that will help the NRC ensure efficient reviews of ATF technologies.

- Commitment to any specific technology from power reactor licensees is important for resource planning. The fuel vendors are strongly pushing ahead and are interacting with NRC staff. The NRC staff is looking forward to receiving scheduling information from power reactor licensees so the staff are able to prepare for license amendments to the desired extent.
- Early communication and pre-application interactions between the staff and applicant/licensee is essential for all licensing actions across the entire fuel cycle
- Staff knowledge is needed on how the technology meets (or fails to meet) the consensus codes and standards and/or regulations prior to submittal
- Staff knowledge of past research and staff ability to conduct appropriate confirmatory research to strengthen the basis for reasonable assurance of adequate safety are needed
- If the data is still being collected, the applicant will need to compensate for the lack of data to provide a safety basis.
- Significant coordination across the NRC Offices is paramount and many technical disciplines are included across the agency.

4 STAKEHOLDER INTERACTIONS

The new paradigm for ATF, higher burnup, and increased enrichment employs early communication with stakeholders to maintain transparency and provide regulatory stability through the issuance of documents, such as the coated cladding ISG, and outreach activities, such as discussions during public meetings, conferences, and NRC-led workshops. The NRC is committed to actively engage in industry project update meetings and support staff participation in experimental program discussions to maintain awareness of industry and DOE efforts to prepare for regulatory reviews. The staff will continue to follow existing NRC policies for all stakeholder interactions regarding ATF, higher burnup, and increased enrichment.

The NRC's enhanced stakeholder communications are designed to:

- Allow NRC staff to become more familiar with ATF concepts, which will help enable more efficient review of ATF applications.
- Remain closely engaged with the organizations and entities acquiring data and adjust this Project Plan as new information becomes available.
- Prevent delayed recognition of required changes to the regulations or guidance to reduce schedule risk. The staff has initiated dialogue with stakeholders to communicate timelines required for modifications to the regulatory infrastructure and to solicit input for changes that may be necessary for the different ATF concepts.
- Allow a more efficient NRC resource reallocation due to industry changes in direction and schedules.
- Provide opportunities for the public to interact with the NRC and provide input since the industry's ATF, higher burnup, and increased enrichment deployment is expected to request an accelerated licensing schedule.

Table 4.1 outlines key meetings and interactions scheduled during the development and review of ATF designs.

Table 4.1 Meetings and Stakeholder Interactions

Meeting	Frequency	Desired Outcome
EPRI/DOE/Idaho National Laboratory (INL) update meetings	Biannually	Assess the technical progress of ATF research and development (R&D). Obtain information necessary for developing analytical capabilities and licensing strategies.
TOPFUEL (rotates between the United States, Europe, and Asia)	Annually	Assess the technical progress of ATF R&D. Obtain information necessary for developing analytical capabilities and licensing strategies.
ATF standards and guidance development activities with the Organization for Economic Co-operation and Development /Nuclear Energy Agency, International Atomic Energy Agency, and international counterparts	Annually	Discuss licensing approach with international counterparts.
Fuel vendor update meetings (rotates from NRC Headquarters to the vendor's headquarters)	Annually (per vendor)	Assess the technical progress of ATF R&D. Obtain information necessary for developing analytical capabilities and licensing strategies (in addition to a number of other non-ATF outcomes).
ATR/TREAT test planning and test observation meetings	As scheduled	Develop an understanding of testing that will characterize the performance characteristics of ATF designs.
International Conferences and Workshops	As scheduled	Understand and coordinate ATF research and knowledge with international counterparts
ATF fuel fabrication facilities tour and audit	As needed	Develop an understanding of manufacturing processes and obtain information for developing licensing strategies.
Participation CRAFT and ESCP committees	As scheduled	Assess the progress of industry and provide NRC viewpoint when requested.
DOE/NRC management meetings	Monthly	Discuss progress and coordinate ATF activities.
Design-specific pre- and post-submittal meetings	As needed	Discuss technical subjects with vendors and licensees. These meetings will contain a public portion when possible for public comment.
NRC-initiated focused-topic meetings	As needed	Provide information and the ability for the public to interact with the NRC on a specific technical and regulatory area(s)

5 INITIATING STAFF ACTIVITIES

Because of design-specific aspects and schedules, the NRC's activities are linked to the industry's progress and plans to deploy ATF, higher burnup, and increased enrichment. For this reason, the agency must have ways for communicating schedules and resource needs in advance of licensing activities. One way to communicate schedules with industry is through routine project manager interactions with vendors and licensees. Power reactor, vendor, and fuel cycle project managers will communicate with their vendors and licensees as needed to maintain awareness of changes to schedules and/or direction. Additionally, fuel vendors host routine update meetings, such as the annual fuel update meetings listed above. As with the informal communication with project managers, these meetings provide awareness of any changes to vendor schedules and/or direction.

The staff will choose to issue generic communications when deemed necessary to obtain industry schedules. To understand fuel cycle vendor and licensee progress and plans, the staff issued Regulatory Issue Summary (RIS) 2019-03, "Pre-Application Communication and Scheduling For Accident Tolerant Fuel Submittals," on November 20, 2019 (ADAMS Accession No. ML19316B342). This RIS seeks ATF scheduling information for preapplication activities, topical report submittals, and other licensing submittals from 10 CFR Part 70, 71, and 72 licensees. Generic communications to power reactor licensees will be issued on an as-needed basis.

This Project Plan provides estimated lead times for each agency activity associated with preparing to conduct effective and efficient licensing reviews of ATF TRs, LARs, and front-end and back-end licensing actions. As the NRC staff gains more experience with these reviews, it will adjust lead times to account for difficulties or efficiencies, as necessary. These lead times dictate when data should be provided by the vendors or licensees ahead of submittals and a formal communication of intent should be made through a response to a RIS, pre-submittal meetings, or other formal interaction with the staff as discussed above.

5.1 Initiating Activities for FeCrAl and Longer Term ATF Technologies

The staff is aware that in the current environment, the focus, momentum, and majority of capital investments for the industry is on coated cladding, doped pellets, higher burnup, and increased enrichment. The NRC staff will start the refinement of the regulatory infrastructure for the other technologies (i.e, FeCrAl cladding, SiC cladding, UN pellets, an extruded metallic fuel) when the industry members provide projected submittal dates for future licensing actions for those technologies. The staff shall maintain discussions with the vendors and possible applicants to learn when future licensing actions will be submitted.

6 PREPARATORY ACTIVITIES

The NRC staff has grouped its preparatory activities into four tasks. The highlights of each task are briefly described below; subsequent sections describe these tasks in full detail.

6.1 Task 1: Regulatory Framework, In-Reactor Performance

- Participate in coordinated PIRT exercises on in-reactor degradation mechanisms and failure modes under a wide array of accident conditions, performance-based metrics, and analytical criteria to ensure acceptable performance.
- Perform a review to (1) evaluate the applicability of existing regulations and guidance for each ATF design, higher burnup, and increased enrichment (2) identify changes to, or the need for, new regulations and guidance, and (3) identify any key policy issues. The table in Appendix A of this Project Plan provide this information for coated cladding, doped pellets, higher burnup, and increased enrichment, which industry plans on adopting in the near term (mid-2020s). The staff are developing plans to resolve the actions contained within the table.
- Identify consensus standards that need to be updated for ATF, higher burnup, and increased enrichment and participate in the update process where appropriate.
- Determine and clarify the regulatory criteria that need to be satisfied for partial or full core use of ATF, higher burnup, and increased enrichment and the regulatory options available to applicants and vendors. The ISG for chromium coated cladding was released to satisfy this task, and the staff are continually assessing the need for additional work on this task for higher burnup and increased enrichment.
- As needed, resolve policy issues and initiate rulemaking and guidance development activities. Because of industry's intent to adopt increased enrichment, the staff has begun the process of requesting approval from the Commission to investigate further.
- Prepare for the submission of LARs by industry that may contain many differing ATF, higher burnup, and increased enrichment adoption strategies. To support planning efforts, the NRC staff provides consistent requests to licensees for information regarding their adoption plans.

6.2 Task 2: Fuel Cycle, Transportation, and Storage Regulatory Framework

- Perform a review to (1) evaluate the applicability of existing regulations and guidance for each ATF design, higher burnup, and increased enrichment, (2) identify changes to, or the need for, new regulations and/or guidance, and (3) identify any key policy issues in the areas of fuel cycle, transportation and dry cask storage.

- Applicable regulations are 10 CFR Part 70, “Domestic Licensing of Special Nuclear Materials”; 10 CFR Part 71, “Packaging and Transportation of Radioactive Material”; and 10 CFR Part 72, “Licensing Requirements for the independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,” which are largely performance based; therefore, the staff does not anticipate identification of gaps or deficiencies in these regulations for licensing or certification of ATF designs, higher burnup, and increased enrichment.
- In preparing staff to receive applications related to ATF concepts and increased enrichments, NRC developed a critical path schedule that was sent to stakeholders on August 26, 2019 (ADAMS Accession No. ML19235A261), identifying key dates for which NRC should receive licensing and certification applications from fuel facilities and fuel vendors to conduct an efficient review in order to support industry’s ability to achieve ATF deployment in 2023.
- Applicability of the current guidance may change as the fuel cycle industry develops plans for manufacturing, transporting, and storing ATF, higher burnup, and increased enrichment. The NRC will monitor the fuel cycle industry’s plans and develop any necessary new or updated regulatory guidance in a timely manner.

6.3 Task 3: Probabilistic Risk Assessment Activities

- The staff will evaluate how industry batch loading of ATF, higher burnup, and increased enrichment may affect the current risk-informed programs such as risk-informed technical specification initiatives 4b and 5b (ADAMS Accession Nos. ML18183A493 and ML090850642, respectively).
- The NRC’s risk-informed oversight activities (e.g., the significance determination process) depend on standardized plant analysis risk (SPAR) models, which may need to be updated to reflect the batch loading of ATF, higher burnup, and increased enrichment. The staff is using the independent confirmatory calculation capabilities, as discussed below in Task 4, to evaluate the new technical information as it is received. The results from these calculations along with requested license amendments will be used to support any needed SPAR model updates.

6.4 Task 4: Developing Independent Confirmatory Calculation Capabilities

The NRC typically performs independent confirmatory calculations to review cases in which uncertainties are large or the margin is small regarding the safety of the proposed change. These calculations performed by the staff provide increased confidence in the applicant’s results. For initial ATF, higher burnup, and increased enrichment licensing for which limited data will be available to formulate and validate models, independent confirmatory calculations will likely be needed. In these instances, the staff that performs the confirmatory calculations must have a clear understanding of (1) the assumptions and limitations of the analytical tools that it uses, (2) the range of conditions for which the code has been validated, and (3) the nature of the validation database.

Based on the information available to date, the staff believes it will be more efficient and effective to pursue relatively minor modifications to existing NRC codes to model near-term ATF fuel concepts, higher burnup, and increased enrichment. The NRC has specifically tailored and extensively validated its codes to evaluate regulatory requirements and phenomena important to safety. These features make the codes easy to use and provide the staff high confidence in the results. At this time, the NRC plans to modify the codes that are developed to analyze fuel performance, thermal hydraulics, neutronics, and severe accidents and source terms. In addition, the staff is considering modifying existing NRC-developed codes to model longer term ATF fuel concepts in cases that require minimal effort. A more detailed discussion of this effort, including the status of NRC staff activities, can be found in Section 10.
Where possible, the NRC will coordinate with DOE to reduce duplication of effort.

6.4.1 Advanced Modeling and Simulation

NRC staff maintain an awareness of the advancements in modeling and simulation for nuclear applications. The staff expects to continue to follow DOE's development efforts in the area of advanced modeling and simulation and to search for opportunities to leverage their capabilities. The staff is aware of efforts to use advanced modeling and simulation in a variety of applications or families of codes: mechanistic codes, steady-state codes, and transient codes. Although advanced modeling and simulation in mechanistic codes can inform experimental programs, improve upon highly empirical correlations, and identify testing priorities, current advanced modeling and simulation tools do not appear to be mature enough to substitute modeling for experiments because of the complex nature of fuel and reactor behavior. Further, the state of knowledge in many areas still only permits semi-empirical modeling of key phenomena. Validation of these tools against relevant data will be essential to demonstrate their potential to support licensing activities. The staff will continue to coordinate with DOE and the national laboratories to better understand the capabilities of the DOE codes to potentially reduce the number of time-consuming and costly experiments and demonstrations.

7 TASK 1: 10 CFR PART 50, 10 CFR PART 52, AND 10 CFR PART 100 REGULATORY FRAMEWORK, INREACTOR PERFORMANCE

To prepare the agency to conduct complete and timely licensing reviews of ATF designs, higher burnup, and increased enrichment, well-developed and vetted positions are needed on potential policy issues that may arise during the review and licensing process. These positions must be communicated to stakeholders clearly and early.

This task contemplates two distinct ATF concept activities that may require changes to the regulatory framework to be performed within the requested timeframes: (1) approval of TRs and LARs to allow batch loading of ATF into NRC-regulated power plants and (2) crediting the safety enhancements of ATF in the licensing basis of NRC-regulated power plants. The regulatory framework changes that may be necessary for each of these activities are likely to be different, and the staff anticipates that such changes will need to be made to address batch loading before making changes needed to credit the safety enhancements of ATF in the licensing basis.

This task also addresses the changes to the in-reactor regulatory framework that may be required to support the implementation of higher fuel burnup and increased enrichment considering the technical issues they present. Generally, the technical issues associated with higher fuel burnup and increased enrichment respectively fall into two categories: (1) fuel integrity (cladding or fuel pellet) and (2) nuclear criticality safety. Emergency Core Cooling System (ECCS) performance embrittlement mechanisms and fuel fragmentation, relocation, and dispersal are examples of fuel integrity technical issues associated with higher burnup. Spent fuel pool criticality and potential fast critical conditions during accident scenarios are examples of the technical issues associated with increased enrichment that fall under nuclear criticality safety. The need to make changes to the regulatory framework to address each technical issue is likely to be different. For example, although licensees will be able to seek approval for the use of fuel with increased enrichment through the exemption process, the staff is investigating revising the regulations so that increased enrichment can be predictably licensed for use outside of the exemption process.

The degree to which existing regulations and guidance are affected and in need of revision, or new regulatory requirements established and new guidance developed, depends on the level of departure from existing fuel designs and burnup and enrichment limits. The regulations at Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” provide principal design and performance requirements. The general design criteria (GDC) listed in Table 7.1 relate to fuel design and overall fuel performance under normal and accident conditions. Regarding ATF, these and additional GDC may be affected if ATF performance becomes more challenging for the control or protection systems that ensure acceptable consequences under accident conditions. For each ATF design, the staff plans to map the hazards and failure mechanisms to the design and performance criteria of the GDC to determine the appropriate applicability and potential need for additional criteria. Regarding higher burnup and increased enrichment, the NRC staff has concluded the GDC discussed within Appendix A to 10 CFR Part 50 will not be affected. While higher burnup and increased enrichment may impact the way compliance with regulatory requirements is demonstrated, the actual principal design and performance requirements provided by the GDC remain applicable.

Note that loading an ATF or increased enrichment fuel design in a specific plant will ultimately need to meet relevant plant-specific criteria. This is especially important for those reactors in the United States that were licensed before the issuance of the GDC (about 40 percent of the operating plants).

Table 7.1 Potentially Affected GDC

GDC No.	Title
1	Quality Standards and Records
2	Design Bases for Protection against Natural Phenomena
10	Reactor Design
11	Reactor Inherent Protection
12	Suppression of Reactor Power Oscillations
13	Instrumentation and Control
20	Protection System Functions
25	Protection System Requirements for Reactivity Control Malfunctions
26	Reactivity Control System Redundancy and Capability
27	Combined Reactivity Control Systems Capability
28	Reactivity Limits
34	Residual Heat Removal
35	Emergency Core Cooling
61	Fuel Storage and Handling and Radioactivity Control
62	Prevention of Criticality in Fuel Storage and Handling

Even if a particular ATF design is unable to demonstrate verbatim compliance, the intent of these principal design and performance requirements should be satisfied or new requirements developed.

7.1 Regulatory Framework Applicability Assessment

To prepare for forthcoming TRs and LARs, the staff determined the applicability of existing regulations and guidance for the near-term ATF concepts, higher burnup, and increased enrichment. Appendix A to this Project Plan, called the Regulatory Framework Applicability Assessment, provides the results of this assessment as of the time of issuance of this Project Plan revision. Each regulation and guidance document listed in Appendix A was assessed for whether it was fully applicable to ATF, higher burnup, and increased enrichment. If a regulation or guidance was found to not be fully applicable, the table identifies this fact and provides a justification. However, the need for regulation or guidance to be fully applicable to ATF, higher burnup, and increased enrichment varies. In some instances, it is not, possibly because other regulations or guidance replace or supersede it. In other instances, it does need to be fully applicable. For some of these instances, NRC staff already discussed and agreed upon a path towards achieving full applicability for the relevant regulation or guidance, and Appendix A will state these closure paths. In other instances, a closure path has not yet been agreed upon, and Appendix A will indicate as such. Appendix A also makes note of some pertinent requirements or actions that regulations or guidance require of an applicant to ensure the regulation or guidance is correctly applied.

Appendix A is non-exhaustive and will be continually updated alongside new revisions to the Project Plan as more information is developed. If/when advancements in an ATF concept not listed on the table demonstrate that the concept could obtain commercial viability, the staff will perform the analysis for that concept.

The identification of a regulation or guidance that is not fully applicable does not mean that ATF, higher burnup, and increased enrichment reviews cannot be performed today; there are regulatory strategies that can be used to proceed forward with a review. For example, sensitivity studies utilizing NRC codes can be performed to ascertain the impact of parameters and their importance on predicting pertinent phenomena. Knowledge of these sensitivities guide the NRC staff's requests for additional information, help with coming to a safety determination through understanding the range of a fuel design's performance, and help form the basis of any potential licensing conditions.

7.2 Licensing Pathways

The tables in Appendix A, Regulatory Framework Applicability Assessment, provide the applicability of existing regulations and guidance for the near-term ATF concepts, higher burnup, and increased enrichment. The staff is developing licensing pathways that provide a simple depiction of the remaining tasks or informational needs for successful (i.e., timely) approval of TRs and plant-specific LARs. They will show the ideal plan or path forward given the current state of technical and regulatory progress in the specified ATF technology, higher burnup, and increased enrichment. As the industry and NRC staff develop more definitive timeframes for submittal of information or completion of tasks, a timeline will be added to the pathways.

The licensing pathways have their limitations. They are not all inclusive, meaning that they do not depict all items a vendor, the NRC staff, or a licensee would have to complete or include to successfully submit or review a TR or LAR. The pathways are also not a timeline, meaning they do not show how long it will take to review and approve a TR or a plant-specific LAR.

The licensing pathways are currently under development and will change as the staff better understand the remaining items/information needs and the timing of receipt from vendors or completion by NRC staff. Appendix B to this Project Plan provides the draft licensing pathway for higher burnup TRs and LARs. Licensing pathways for increased enrichment, coated cladding, and doped pellets are under development and will be shared with stakeholders at the appropriate time. Pathways will be developed for the other ATF concepts when enough details are known to perform a regulatory framework applicability assessment for that concept.

7.3 Additional Considerations

Aspects of ATF, higher burnup, and increased enrichment designs or implementation strategy could expand the scope, level of complexity, and schedule of the staff's review of TRs and LARs, such as the following:

- Environmental concerns
- Changes in accident source term and operational source term
- Industry may take an incremental approach to higher burnup and increased enrichment
- Lack of technical data for independent confirmatory calculations

Licensees seeking to adopt increased enrichment and higher burnup beyond the current licensed limits will need to submit a LAR with a complete description of the potential environmental impacts of the request. The staff review of these environmental impacts could be a source of additional complexity resulting in additional schedule risk. Specifically, the anticipated enrichment levels up to 10 weight-percent U-235 and burnup levels above 62 GWd/MTU are outside the conditions for use of Table S-4 (10 CFR 51.52(c)) for the environmental impacts of the transportation of fuel and waste. Thus, each LAR review would need a full description and detailed analysis performed by the staff of the environmental effects of transportation of fuel and waste to and from the reactor for these higher enrichment and burnup levels. Any such analysis would have to address a number of competing factors that could lower or raise environmental impacts such as batch core loads, increased refueling intervals, revised number of fuel assemblies per shipment, increases in radionuclide inventory, and others where the needed data has yet to be determined. There are also expected changes to the plant-specific safety analysis which also would require a corresponding environmental finding with the safety finding. As with the analysis of transportation of fuel and waste, each environmental review by the staff would need to evaluate the related plant-specific environmental impacts to provide information on any changes from previous environmental analyses, such as from license renewals. To minimize this additional complexity for each LAR, the staff may need to consider if it is possible to generically evaluate the environmental impacts. To this end the staff is evaluating past studies, such as NUREG-1437 Addendum 1 and NUREG/CR-6703 along with assessing the available fuel performance analyses, data, and studies to determine if a generic study of ATF environmental impacts is feasible. The necessity of this effort will become clearer as NRC staff continues engagement with industry and the fuel vendors.

Accident tolerant fuel concepts may affect fission product release kinetics and chemical form, core melt progression and relocation, and mechanical and chemical interactions under severe accident conditions relative to 5 weight percent UO_2 fuel in uncoated zirconium alloy cladding. These effects may impact accident source term. Higher fuel burnup and increased enrichment may also effect changes in accident source term and operational source term via changes in decay heat load and isotopic inventory. Should these source terms be impacted, licensees will need to evaluate the impact of the change to the accident analyses and offsite doses and may need to revise their accident analyses of record and environmental analyses. Additional challenges may exist if the revised source terms result in environmental impacts that are not captured in or bounded by the impacts discussed in NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," (ADAMS Accession No. ML13106A241). This could complicate successful completion of a finding of no significant impact for an exemption request. The NRC staff is performing MELCOR calculations for representative plants to determine whether existing source term guidance (e.g., Regulatory Guide 1.183 (ADAMS Accession No. ML003716792)) is applicable for near-term accident tolerant fuel concepts and for 5 weight percent UO_2 fuel in zirconium alloy cladding over the increased ranges of burnup and enrichment being proposed. The results from the MELCOR calculations may result in a revision to RG 1.183 to incorporate the new information, if necessary.

The staff understands industry may take an incremental approach in moving to higher burnup and increased enrichment. Therefore, the NRC staff envisions near-term and longer term strategies for moving forward with the licensing of higher burnup fuels and fuels with increased enrichment. In the near-term, licensees may need to request exemptions to existing regulations on a licensee-specific basis for the use of increased enrichment and demonstrate compliance with safety requirements along with the exemption criteria. Should widespread adoption of these technologies become apparent, the NRC staff may utilize rulemaking in a longer term strategy to update existing regulations on enrichment levels to facilitate a more predictable licensing process.

The independent confirmatory calculation capabilities highlighted in this Project Plan are used to expedite staff reviews. As discussed in Section 10 of this Project Plan, these capabilites are heavily dependent on material property and experimental data to ensure that a computer code appropriately models key phenomena and accurately predicts the parameters of safety importance. If this technical data is not received or is incomplete, the staff can account for uncertainties through the use of limitations and conditions for TRs and license conditions for LARs. Additionally, the staff can perform sensitivity analyses to determine which material or physical propertiese hav the greatest effect on safety and tailor the limitations and conditions accordingly.

7.4 Lead Test Assemblies

LTA programs provide pool-side, post-irradiation examination data collection; irradiated material for subsequent hot-cell examination and research; and demonstration of in-reactor performance. This characterization of irradiated material properties and performance is essential for qualifying analytical codes and methods and developing the safety design bases for new design features or new fuel designs.

The NRC published a letter to the Nuclear Energy Institute on June 24, 2019, “Clarification of Regulatory Path for Lead Test Assemblies,” (ADAMS Accession No. ML18323A169) that documents the agency’s position concerning criteria for the insertion of LTAs under 10 CFR 50.59 without additional NRC review and approval. LTA programs for ATF designs, higher burnup, increased enrichment may require LARs, depending on the scope of the LTA campaign and the licensing basis of the reactor.

7.5 Initiating Activity

The staff’s expenditures associated with developing regulatory strategies and the framework for design-independent ATF licensing began in fiscal year 2017 and will continue as long as DOE and industry actively pursue ATF, higher burnup, and increased enrichment development. The staff’s expenditures to support design-specific regulatory hurdles will begin upon formal notification from a vendor of its intent to pursue licensing of a specific design.

7.6 Deliverables

At this time, there are no additional PIRTs or literature reviews planned for in-reactor activities. However, if future developments result in planned literature reviews or PIRTs, the staff will follow the schedule below.

Table 7.2 Anticipated In-Reactor Deliverables*

Title	Due Date (near term/longer term)
Map of hazards and failure mechanism to GDC, regulations, and guidance documents.	6–12 months from completion of the PIRT exercise or literature review
Develop or revise guidance to address any identified necessary changes.	24–48/36–60 months from completion of the PIRT exercise or literature review
Develop rulemaking to address any identified necessary changes.	24–48/36–60 months from identification of required change

* The technical lead is the NRR Division of Safety Systems, Nuclear Methods and Fuel Analysis Branch.

8 TASK 2: REGULATORY FRAMEWORK FUEL FACILITIES, TRANSPORTATION, AND STORAGE

The NRC regulations for fuel cycle activities of fuel cycle facilities (enrichment and fabrication facilities), radioactive material transportation, and spent fuel dry storage are found in 10 CFR Part 70, 10 CFR Part 71, and 10 CFR Part 72, respectively. The regulations identify general performance requirements and have been used for licensing a broad spectrum of fuel cycle facilities and for the certification of a broad spectrum of transportation packages and spent fuel storage casks. The NRC does not expect these regulations to need modification to accommodate the fabrication, transportation, or storage of ATF concepts, increased enrichment, and higher burnup.

For the front-end of the fuel cycle, which includes enrichment of the feed material, fuel assembly fabrication and transportation of feed material and fresh fuel assemblies, new cladding materials and increased enrichment may present new and unique technical and regulatory issues; however, current guidance, review plans, and regulatory criteria are adequate to address these issues. The NRC staff recognizes that licensing and certification actions related to the production and transportation of fresh fuel with new cladding materials and increased enrichment will occur in the near term; therefore, any issues or challenges must be addressed in the near-term for successful deployment. To prepare the agency to conduct near-term licensing and certification reviews of ATF concepts with or without increased enrichment, discussion of licensing and certification strategies and approaches between applicants and NRC staff will need to be undertaken. Any potential technical or policy issues the NRC staff identifies will be communicated to stakeholders promptly.

For the back-end of the fuel cycle, which includes transportation and storage of spent fuel at higher burnup and increased enrichment, the NRC staff will continue to monitor industry's initiatives and licensing actions for reactor operation, and assess whether revisions to current guidance, review plans, and regulatory criteria may be warranted. The NRC staff recognizes that licensing and certification actions related to the transportation and storage of such spent fuel will not occur in the near term. The NRC staff will engage with industry as plans on the back-end of the fuel cycle are developed and will update this plan accordingly.

This task contemplates the changes to the regulatory framework that may be required to support the implementation of increased enrichment, considering the technical and regulatory issues it presents. When considering the safe transportation of material for the front-end of the fuel cycle, the notable technical issue associated with increased enrichment pertains to nuclear criticality safety for UF_6 transportation and fresh fuel assemblies. Fuel assemblies (both fresh and irradiated) that rely on the fuel assembly structural performance to remain intact under accident conditions and the criticality evaluation of a single UF_6 package without using the exception in 10 CFR 71.55(g) are examples of the technical issues that fall under fuel integrity and nuclear criticality safety, respectively. Benchmarking criticality analyses for increased enrichment fuel and burnup credit analyses for spent fuel storage and transport are also examples of the technical issues that fall under nuclear criticality safety. The regulatory framework changes that may be necessary to address each technical issue are likely to be different; however, the staff does not anticipate that such changes will need to be made before higher fuel burnup or increased enrichment fuel can be licensed or certified for general use in reactors. Additional information on these technical issues are discussed in detail in Section 8.1.4 of this Project Plan.

To prepare for the review of fuel facility licensing, transportation packages, and spent fuel storage designs, the NMSS staff determined the applicability of existing regulations and guidance for the near-term ATF concepts, higher burnup, and increased enrichment. Item numbers 24 through 35 of Appendix A to this Project Plan provides the results of this assessment as of the time of issuance of this revision.

The review guidance documents in Appendix A draw on industry experience in the fabrication, transportation, and storage of Zr-clad UO_2 fuel with up to 5 weight percent enrichment and burnup up to approximately 62 GWd/MTU rod average (or equivalent). The NRC may need to supplement some of the guidance to address safety-related issues that could arise from ATF designs that involve different fuel or clad materials, higher burnup, increased enrichment, or changes in the processes and systems used to produce or manage the ATF. Potential areas for which review guidance may be expanded include criticality safety for systems with increased enrichment and/or higher burnup, fuel or cladding material properties that are used in the analysis of transportation or storage packages, and failure mechanisms that must be considered for irradiated fuel other than Zr-clad UO_2. Two specific examples for which guidance may be developed are material properties for FeCrAl alloys and SiC materials that are used as ATF cladding.

The NRC staff will continue to monitor industry plans for enriching, fabricating and transporting unirradiated ATF fuel designs and for transporting and storing irradiated ATF, including those with increased enrichment and higher burnup. When the staff believes that supplemental information or guidance would facilitate the preparation and review of applications involving the fabrication, transportation, and storage of ATF designs, higher burnup, and increased enrichment, it will discuss this with stakeholders and take actions as needed.

8.1 Facility, Transportation, and Storage Reviews

The regulatory reviews to support the development and batch deployment of ATF designs with and without increased enrichment will occur in several fuel cycle areas, which include production (enrichment and fuel fabrication), transportation of UF_6 feed material, transportation of fresh fuel assemblies, storage of spent fuel, and transportation of spent fuel. The sections below discuss these various reviews.

8.1.1 Uranium Enrichment and Fuel Fabrication Facility Reviews

The uranium enrichment facilities that produce enriched uranium, as well as the fabrication facilities that would produce near term ATF concepts with and without increased enrichment, would conduct operations that are similar to currently licensed ones. However, to produce fuel with enrichments above the 5 weight percent uranium-235, these licensees will have to submit amendments to increase their licensed enrichment limits. Fuel fabrication operations that would use new processes for producing a different type of fuel material (e.g., uranium alloy or UN) are expected to submit amendments to address both increased enrichment as well as the new processes. Licensees will use the regulations at 10 CFR 70.72, "Facility change and change process," to determine whether NRC approval is required before implementing a change for the fabrication of ATF.

The staff is currently engaged with licensees of fuel cycle facilities to understand the status of their plans and the anticipated timing of their license amendment submittals

8.1.2 Uranium Feed Material and Unirradiated Fuel Transportation Package Reviews

For increased enrichment in UF_6 feed material and fresh fuel assemblies, changes to the regulations are not necessary to accommodate industry plans; however, licensing and certification challenges may exist, as discussed below in Section 8.1.4.

The staff has reviewed and still expects vendors that are developing ATF to request approval of additional packages for transporting LTAs from the fabrication facilities to reactors for test irradiation. As the industry prepares for the batch loading of ATF both with and without increased enrichment, the staff expects to receive requests for the approval of transportation packages that allow large-scale (i.e., batch) shipment of uranium feed material (currently UF_6) and unirradiated ATF assemblies. The staff will review these requests against the requirements of 10 CFR Part 71 and will use the guidance in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report," (ADAMS Accession No. ML20234A651) to perform the safety reviews. The NRC staff has supported literature reviews and assessments of data needs that focus on criticality and shielding safety (code validation) and materials properties and performance of fuel cladding (See Section 11 of this Project Plan for a reference to the complete list of literature reviews). These literature reviews and data needs efforts are expected to help the staff develop additional regulatory guidance for transportation of fuel with alternative cladding types and increased enrichment, if required.

The staff is currently engaged with fuel cycle facility certificate holders to understand the status of their plans and the anticipated timing of their transportation certificate amendment submittals.

8.1.3 Irradiated Fuel Transportation Package and Storage Cask Reviews

The agency expects any shipments of irradiated ATF LTAs or rods from ATF LTAs to be made in NRC-approved transportation packages. For large-scale shipment of irradiated ATF assemblies with or without higher burnup, the staff expects to receive requests for the approval of transportation packages under 10 CFR Part 71. For shipments of a limited number of shipments of irradiated LTAs over a limited timeframe, requests could be made under 10 CFR Part 71 (i.e., letters of special authorization), similar to that expected for unirradiated

LTAs. The NRC will review these requests against the requirements of 10 CFR Part 71, and the staff will use NUREG-2216 for the safety review.

If NRC-licensed reactors use ATF assemblies and later wish to move those assemblies into dry storage, such sites will need storage systems that are designed to contain irradiated ATF assemblies and are licensed under 10 CFR Part 72. The NRC will review these requests against the requirements of 10 CFR Part 72, and the staff will use NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities - Final Report," ADAMS Accession No. ML20121A190) for the safety review. Future updates of this Project Plan will address such systems as the industry's plans become more certain.

The NRC staff plans to support PIRT efforts that focus on the identification and evaluation of material properties and fuel degradation mechanisms to support the review of transportation packages or storage systems for irradiated ATF. These PIRT efforts should help the staff develop additional regulatory guidance for irradiated ATF, if required.

The staff is currently engaged with fuel cycle facility certificate holders to understand the status of their plans and the anticipated timing of their certificate amendment submittals.

8.1.4 Potential Challenges

Certain aspects of ATF designs with or without increased enrichment and higher burnup or fuel cycle implementation strategies could affect the scope, level of complexity, and schedule of the staff's review. This section discusses the potential challenges that may need to be addressed to efficiently license these designs.

The major fuel cycle changes that are possible as a result of ATF development include (1) increased enrichment (i.e., greater than 5 weight-percent U-235 enrichment), (2) higher burnup above 62 GWd/MTU rod average (or equivalent) (3) different fuel material (e.g., Cr--doped UO_2, UN, or metallic fuel material), and (4) different cladding (e.g., FeCrAl, SiC, or coated Zr cladding). The number and nature of changes in these areas affect the effort required to review proposed fuel cycle changes. Table 9.1 identifies potential regulatory actions for the fuel cycle facilities and operations that might be required for these potential fuel cycle changes.

Table 8.1 Potential ATF Fuel Cycle Action and Associated Regulatory Actions

Potential ATF Fuel Cycle Action	Potential Regulatory Actions at Affected Facilities/Operations			
	Enrichment Facility	**Fuel Fabrication Facility**	**Transportation**	**Irradiated Fuel Dry Cask Storage Facility**
Increased enrichment	License amendment to produce higher enrichment material	License amendment to manufacture higher enriched fuel	Applications for new or amended transportation certificates for unirradiated, enriched feed material (e.g., uranium hexafluoride package), and unirradiated and irradiated fuel assemblies	Applications for new or amended storage licenses or certificates of compliance are expected for increased enrichment
Higher burnup	Not applicable	Not applicable	Applications for new or amended transportation certificates for irradiated fuel assemblies with higher burnup	Applications for new or amended storage licenses or certificates of compliance are expected for higher burnup fuel
Different fuel material		Facility changes that do not meet the criteria of 10 CFR 70.72(c) will require NRC approval	Applications for new or amended transportation certificates for unirradiated fuel and irradiated fuel	Applications for new or amended storage licenses or certificates of compliance for ATF assemblies
Different fuel cladding			Applications for new or amended transportation certificates for unirradiated fuel and irradiated fuel	Applications for new or amended storage licenses or certificates of compliance to store ATF assemblies

The greater the differences between an ATF design and Zr-clad UO_2, the more likely supplemental review guidance will be required and the more likely the review will require greater staff effort. As an example, one potential ATF fuel material, UN, is more susceptible to chemical reactions (e.g., water, air) than UO_2. This hazard needs to be considered in the design and operation of a facility that produces or stores this material, and the NRC staff will need to review such facility designs and safety controls as part of the licensing process.

8.1.4.1 Challenges for Transportation of Uranium Feed Material and Unirradiated Fuel

The regulations in 10 CFR 71.55(g) grant an exception from the consideration of moderator intrusion for the transportation of UF_6 enriched to 5 weight percent or less. Transportation of UF_6 enriched to greater than 5 weight percent will require the design and certification of new packages, the modification of currently existing approved packages, an exemption from the regulations that require evaluation of a single package with optimum moderation for enrichments greater than 5 weight percent uranium-235.

In addition to challenges for approval of transport of UF_6 at increased enrichment (greater than 5 weight percent), it should be noted that American National Standards Institute (ANSI) N14.1, "Nuclear Materials — Uranium Hexafluoride – Packagings For Transport," only applies to enrichments up to 5 weight percent uranium-235 for the 30B and 30C cylinders; however 12A/12B cylinders which can hold up to 460 pounds of UF_6 are authorized for enrichments up to 12.5 weight percent uranium-235. DOT regulations in Title 49 of the *Code of Federal Regulations* (49 CFR) 173.420 state that UF_6 packaging (whether fissile, fissile excepted, or non-fissile) must be designed, fabricated, inspected, tested and marked in accordance with American National Standard N14.1 that was in effect at the time the packaging was manufactured. DOT regulations in 49 CFR 173.417, which provide requirements for shipment of UF_6 heels without a protective overpack also limit the enrichment of 30B and 30C cylinders to 5 weight percent uranium-235. In addition to an NRC approval for shipment in a packaging using a 30B or 30C cylinder, a special permit from DOT will be needed, if an exemption to the NRC requirements are used for approval.

Benchmarking criticality analyses for fissile material enriched to greater than 5 weight percent uranium-235 presents a challenge due to the limited number of critical experiments in that range. Applicants for package approval could potentially overcome this challenge by:

- performing new critical experiments to validate criticality calculations for 5-10 weight percent uranium-235,
- relying on sensitivity/uncertainty analysis methods to develop new critical experiments,
- relying on sensitivity/uncertainty analysis methods to determine that existing experiments are applicable to 5-10 weight percent uranium-235,
- increasing the one-sided k-effective tolerance factor to account for uncertainties in criticality code performance due to the number of applicable critical experiments for benchmarking, or
- using some combination of the above options.

In addition, applications to transport unirradiated ATF for batch loading may credit the structural properties of the fuel cladding to maintain the configuration of the fuel during normal conditions of transport and hypothetical accident conditions. While coated zirconium cladding is expected to have properties similar to those of conventional zirconium cladding, confirmatory data on ATF cladding mechanical properties and fatigue performance will likely be needed to support the safety analyses. Similarly, applications to transport fuel that uses other cladding materials (e.g., FeCrAl, SiC) will need to be accompanied by data to demonstrate adequate structural performance.

8.1.4.2 Challenges for Transportation and Storage of Spent Fuel

A transportation package or storage cask that is evaluated containing spent fuel will have the same criticality benchmarking concerns listed above for unirradiated material. If a transport package or storage cask is evaluated for burnup credit, instead of conservatively evaluating it as fresh fuel, the isotopic depletion analyses will need to be validated for the increased enrichment and burnup levels. In addition to validating the criticality analysis, the accuracy of depletion calculations to calculate the source term for the shielding analyses should be evaluated for burnup greater than 62 GWd/MTU rod average (or equivalent).

In addition, the data needs for fuel cladding performance discussed above are also present for irradiated cladding. Cladding mechanical properties are influenced by in-reactor irradiation and the vacuum drying operations that are performed when the fuel assembles are loaded into the transportation or storage casks. Increased levels of burnup and new fuel pellet compositions can also influence cladding stresses and, consequently, affect cladding performance during fuel loading, transportation, and storage operations. Further, the thermal metrics in the NRC guidance for allowable cladding temperatures are not necessarily applicable to ATF. Applicants for transportation package and storage cask approval could potentially overcome these challenges by:

- providing data from mechanical property and fatigue tests of ATF cladding irradiated to the requested allowable burnup (e.g., from LTAs)
- providing data to justify allowable cladding temperatures during drying operations, considering the effects of cladding creep and potential mechanical property changes
- providing data to justify the thermal properties of ATF cladding that are used in the transportation package or storage cask thermal analyses

Applications to renew dry storage system licenses and certificates of compliance must also evaluate and, if applicable, propose an aging management approach for aging-related degradation of ATF cladding. NUREG-2214, “Managing Aging Processes In Storage (MAPS) Report: Final Report,” (ADAMS Accession No. ML19214A111) includes an evaluation of aging mechanisms for traditional Zr-clad fuel; these evaluations are not necessarily applicable to ATF. As a result, the NRC staff expects that a renewal application provide data to demonstrate that age-related phenomena not at play during extended dry storage of spent ATF.

8.1.5   Initiating Activity

The staff’s expenditures associated with developing regulatory strategies and the framework for design independent ATF fuel cycle licensing began in FY 2017 and will continue as long as

DOE and industry are actively pursuing ATF, higher burnup, and increased enrichment development. The staff's expenditures to support ATF designs and licensee-specific fuel cycle activity begins when an applicant meets with the staff to discuss its proposed submittal, or when the staff receives an application to review.

8.1.6 Deliverables

At this time, there is one PIRT that is planned for spent fuel transportation and storage activities.

Table 8.2 Anticipated Fuel Cycle, Transportation and Storage Deliverables*

Title	Due Date (near term/longer term)
PIRT on cladding performance during spent fuel transportation and storage	FY 2023
Develop or revise guidance to address any identified necessary changes.	24–48/36–60 months from completion of the PIRT exercise or literature review

* The technical lead is the NMSS Division of Fuel Management

9 TASK 3: PROBABILISTIC RISK-ASSESSMENT ACTIVITIES

The NRC uses probabilistic risk assessments (PRAs) to estimate risk to investigate what can go wrong, how likely it is, and what the consequences could be. The results of PRAs provide the NRC with insights into the strengths and weaknesses of the design and operation of a nuclear power plant. PRAs cover a wide range of NRC regulatory activities, including many risk-informed licensing and oversight activities (e.g., risk-informed technical specification initiatives, the significance determination process portion of the Reactor Oversight Process). These activities make use of both plant-specific licensee PRA models and plant-specific NRC PRA models. The NRC uses the former models predominantly for licensing and operational activities and the latter models predominantly for oversight activities. A key tenet of risk-informed decision-making is that these models reflect the as-designed, as-operated plant. For this reason, these models should be updated to reflect significant plant modifications. The introduction of significantly different fuel into the reactor core has the potential to affect these models, particularly once the reactor core composition significantly influences the plant's response to a postulated accident (e.g., time to fuel heat up and degradation, amount of total hydrogen generation, higher decay heat from increased enrichment).

Activities associated with the development of capabilities to support risk-informed regulatory activities following the implementation of ATF, higher burnup, and increased enrichment could require significant NRC resources. Information about the industry's intended approach is needed to create a meaningful plan. Early interactions within the PRA community on ATF, higher burnup, and increased enrichment activities, including early preapplication meetings, have been used to encourage industry to ensure that the approach being pursued is consistent with the related regulatory requirements and staff guidance. This plan recognizes that the staff's PRA-related preparatory work involves two separate, but closely related, aspects:

(1) The staff need to prepare for, and review, PRA-related information submitted as part of the licensing process for batch loading of ATF, higher burnup, increased enrichment, and incorporation of the safety enhancements of ATF into the licensing basis.

(2) The staff need to develop PRA-related capabilities that allow it to do the following effectively:

- Review risk-informed licensing applications and ensure that applicants are using acceptable PRA models once ATF, higher burnup, and/or increased enrichment is implemented.
- Perform risk-informed oversight evaluations (e.g., significance determination process) once ATF, higher burnup, and/or increased enrichment is implemented.

The nature of item 1 is highly dependent on the approach taken by each vendor or licensee, or both, in its licensing application. However, item 2 is somewhat independent of the licensing approach for the batch loading of ATF; therefore, this plan currently focuses more attention on item 2.

As illustrated by the above categorization, PRA is more broadly relevant to ATF than simply the incorporation of ATF safety enhancements into the licensing basis. Again, this stems from the fact that the NRC uses a risk-informed licensing and oversight approach that relies on plant-specific PRAs that represent the as-built and as-operated plant. Near-term ATF designs may have a limited impact on PRA modeling, whereas longer term ATF designs may have a more significant impact on PRA modeling. Incremental increases in fuel burnup and enrichment (such as increases on the orders of tenths of a percent enrichment or low single digits of gigawatt days per metric ton of burnup) may have only a limited (or no) impact on PRA modeling. However, the more appreciable increases in fuel burnup and enrichment that are anticipated, especially in combination with the other cladding and fuel changes associated with adoption of ATF, may have a more significant impact on PRA modeling. In general, the PRA modeling changes in question include the following:

- selection of core damage surrogates used in defining PRA end states (e.g., peak nodal clad temperature of 1,204 degrees Celsius, water level at two-thirds active fuel height)
- accident sequence modeling assumptions used to create event tree models that define the high-level successes and failures that can prevent core damage (e.g., late containment venting is required for avoiding core damage)
- system success criteria used in fault trees for defining the minimum hardware needed to fulfill specific mitigation functions (e.g., two relief valves are needed to prevent injection pump deadhead when feed and bleed cooling is used for a transient with no feedwater)
- sequence timing assumptions used in accident sequence modeling, success criteria determinations, and human reliability analysis to establish relevant time windows (e.g., feed and bleed cooling initiated within 20 minutes of low steam generator water level).

The staff will need to ensure that licensees' PRAs continue to use acceptable models and assumptions as part of the implementation of ATF and update the NRC's models (as necessary) to reflect the ATF plant modifications, higher burnup, and increased enrichment. PRA models are not required under 10 CFR Part 50 and their use is not a prerequisite for approval of an ATF design, higher burnup, increased enrichment, or the batch loading into a particular plant. That said, plants using PRA to support risk-informed operational programs (e.g., 10 CFR 50.69, risk-informed TS initiatives) should continue to update their PRAs so that they realistically reflect the as-built, as-operated plant. The NRC expects that modifications affecting a plant's risk profile (e.g., ATF, improved reactor coolant pump seals, etc.) will be incorporated into licensee's PRA models under their existing PRA maintenance programs.

Much of the needed underlying deterministic knowledge to address these points can leverage the work covered elsewhere in this plan, particularly the fuel performance, thermal hydraulics, and severe accident calculation capability development. It is envisioned that much of the analytical investigation needed to assess PRA-related impacts and support PRA-related changes in the agency's SPAR models can use the MELCOR modeling and analysis discussed in Section 10 of this Project Plan. If needed, additional confirmatory analysis could also be pursued using MELCOR plant models developed for other NRC initiatives, such as those documented in NUREG-1953, "Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Surry and Peach Bottom," (ADAMS Accession No. ML11256A023), and NUREG-2187, "Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Byron Unit 1," (ADAMS Accession Nos. ML16021A423 and ML16022A062). This leveraging of resources between severe accident analysis tools and PRAs is routine.

In the nearer term, PRA-related impacts can be assessed using the general knowledge being developed in these other ATF Project Plan areas in conjunction with one or more pilot efforts using the existing SPAR models. Such pilots would help gain risk insights, assess the potential changes in core damage frequency (CDF) and large early release frequency (LERF),[4] and highlight areas where existing guidance[5] or methods may require refinement to address the implementation of ATF, higher burnup, and increased enrichment.

As a final introductory point, engagement on PRA-related topics both within the staff and with external stakeholders is important at all stages. Effective interaction will foster a common understanding of the acceptability of PRA methods used to model plant modifications and the impact that will ultimately be realized when these modifications are integrated into PRAs and risk-informed processes. Effective interaction can also ensure that information required to develop PRA modeling assumptions related to plant modifications is properly coordinated with the deterministic review. In this case, PRA relevance has been identified early in the process, and time is available to address the PRA-related needs in a thoughtful and symbiotic manner.

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[4] Differences in LERFs could occur because of (1) differing fuel heatup and degradation time windows, (2) the generation of differing amounts of in-vessel hydrogen, (3) changes to the fission product release rates, and (4) shifts in the balance of challenges to other vessel and connected piping system components stemming from higher in-core temperatures before the relocation of debris.

[5] This guidance encompasses the guidance used in risk-informed licensing and oversight (e.g., the SRP; relevant RGs; Inspection Manual Chapter (IMC) 0609, "Significant Determination Process," dated April 29, 2015; the risk-assessment standardization process manual). In reality, most of this guidance would not require revisions because the concepts and processes would continue to apply. However, some aspects could require modifications, such as those involving the LERF multipliers used in IMC 0609, Appendix H, "Containment Integrity Significance Determination Process," dated May 6, 2004, whereas some guidance may benefit from additional discussion of ATF impacts.

For the purpose of identifying the PRA-related milestones, the following key assumptions are necessary (some restate assumptions made elsewhere in this plan):

- The timing of PRA-related efforts will be cross-coordinated with those of the previously identified partner areas (e.g., severe accident analysis) to allow the leveraging of deterministic work to make the PRA-related efforts efficient. This approach will be reassessed as the industry's perspective evolves on the potential risk significance of ATF designs, higher burnup, and increased enrichment, as they relate to future submittals aimed at leveraging ATF to reduce regulatory requirements.
- This plan does not account for new regulatory initiatives that might be requested to maximize the operational or economic benefit of ATF, such as the following:
  - modifications to the categorization process in 10 CFR 50.69, "Risk-Informed Categorization and Treatment of Structures, Systems and Components for Nuclear Power Reactors," associated with the use of relative (as opposed to absolute) CDF/LERF criteria[6]
  - reduction of requirements associated with security and emergency preparedness programs
  - rulemaking initiatives that might be requested to facilitate rapid adoption of increased enrichment.

6 This initiative has been mentioned as a potential limitation in the degree of benefit that would be gained in risk-informed licensing space, and it contrasts to the use of absolute risk measures in other relevant risk-informed licensing activities such as risk-informed technical specification initiatives.

Table 9.1 PRA Activities—Milestones

	Milestone	Input Needed	Lead Time/ Duration	Needed By
1	Participate in internal and external discussions and knowledge development related to ATF (e.g., internal working group meetings, public meetings)	N/A	Ongoing	N/A
2	Complete licensing reviews, including potential TRs or industry guidance, related to the risk-informed aspects of ATF, higher burnup, and increased enrichment licensing	More information regarding the specific licensing approach	TBD	TBD
3	Complete a SPAR pilot (as necessary) of a near-term ATF design, higher burnup, or increased enrichment for a boiling water reactor (BWR) and pressurized water reactor (PWR) subject plant to assess CDF/LERF impacts, gain risk insights, and identify potential improvements to guidance	Deterministic knowledge base being developed under other tasks (e.g., MELCOR analysis)	6 months	1 year before the first near-term ATF core load[1]
4	Complete a SPAR pilot (as necessary) of a longer term ATF design for a BWR and PWR subject plant to assess CDF/LERF impacts, gain risk insights, and identify potential improvements to guidance	Deterministic knowledge base being developed under other tasks (e.g., MELCOR analysis)	6 months[2]	1 year before the first longer term ATF core load[1]
5	Update guidance (as necessary) to support licensing and oversight functions for plants making modifications (if necessary) for ATF, higher burnup, or increased enrichment	Completion of the items above	1 year	Before the ATF core load[1]
6	Update agency PRA models to reflect ATF-related changes to the as-built, as-operated plant for relevant plants/models	Details of the plant modifications	1 year[3]	As needed to support the agency's risk evaluations

[1] Here, core load means the replacement of a large proportion (e.g., 50 percent or more) of the core with ATF assemblies, assuming that non-ATF fuel will be generally more limiting to PRA impacts if a mixed core exists.

[2] This task should be performed sequentially after the equivalent task for near-term ATF designs as long as both near -term and longer term designs are of regulatory interest.

[3] This would occur after approval of the associated licensing action.

Table 9.2 PRA Activities—Deliverables

Title	Lead Time
Safety evaluation contributions for TRs and LARs related to ATF	TBD
Report documenting results and recommendations from a near-term ATF SPAR pilot study	1 year before the first near--term ATF core load
Report documenting results and recommendations from a longer term ATF SPAR pilot study	1 year before the first longer term ATF core load
Updated guidance (e.g., risk-assessment standardization project guidance changes) to support licensing and oversight functions for plants making ATF-related modifications	Varies depending on the documents that require modifications
Updated agency PRA models to reflect ATF-related changes to the as-built, as-operated plant for relevant plants/models	As needed to support the agency's risk evaluations

10 TASK 4: DEVELOPING INDEPENDENT CONFIRMATORY CALCULATION CAPABILITIES

Independent confirmatory calculations are one of the tools that the staff can use in its safety review of TRs, LARs, and front-end and back-end licensing actions. Confirmatory calculations provide the staff insight on the phenomenology and potential consequences of transient and accident scenarios. In addition, sensitivity studies help to identify risk significant contributors to the safety analyses and assist in focusing the staff's review. RG 1.70, Revision 3, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," (ADAMS Accession No. ML011340122) identifies the standard format and content of safety analysis reports for nuclear power plants, and the SRP identifies the criteria that the staff should use to review licensee safety analyses. The NRC plans to continue to develop independent confirmatory analysis tools that support robust SEs and provide insights into safety significant factors for each ATF design, higher burnup fuels, and fuels with increased enrichment. Vendor codes used for ATF, higher burnup, and increased enrichment modeling capabilities will likely be based on smaller data sets than those of the current Zr-UO_2 models. This will result in greater uncertainty in the results of the safety analyses and the margins to the specified acceptable fuel design limits. For these reasons, confirmatory calculation capabilities will be critical for generating confidence in the safety assessment of ATF, higher burnup, and increased enrichment against all applicable regulatory requirements. A confirmatory code can be used to independently quantify the impact of modeling uncertainties and support more efficient reviews with the potential for fewer requests for additional information. Finally, the experience and insights gained by developing an in-house code can be leveraged in reviews of externally developed models and methods, thus making reviews more efficient and effective.

The staff identified four technical disciplines needing calculation capability development to support safety reviews: (1) fuel performance, (2) thermal hydraulics, (3) neutronics, and (4) severe accidents. The NRC has developed a suite of codes to analyze these disciplines, and they have been used successfully to support regulatory decision-making. Further development of these codes is appropriate to ensure that the NRC has the capability to analyze ATF designs, higher burnup, and increased enrichment. Having tools that the staff can use to analyze ATF, higher burnup, and increased enrichment will be particularly important because applicants will use computational tools to demonstrate that they have met fuel safety acceptance criteria and because, in some cases, the properties and models for ATF, higher burnup, and increased enrichment within the computational tools will be based on limited experimental data.

The development of calculation capabilities will proceed with similar activities in each area, as follows:

- PIRT exercises help ensure that all new phenomena important to safety have been identified and considered in the planning phases. PIRT results will be used to inform code development efforts.
- Scoping studies or code evaluations will be performed to identify the architecture and model updates needed to model various ATF concepts and designs.
- Where necessary, code architecture modifications will be made (e.g., to remove Zr/UO_2 hard-wired properties and assumptions or to solve the governing equations for non-cylindrical geometry).
- Material properties will be added, and new models will be developed, where necessary.
- Integral assessment of the updated codes will be completed and documented. It is likely that results from integral assessments and uncertainty studies performed using updated codes will be used to revisit and maintain PIRT products.

Figure 10.1 depicts a generic schematic of tasks associated with developing calculation capabilities for near-term ATF, higher burnup, and increased enrichment, whether such capabilities are developed by the applicant, DOE, or the NRC.

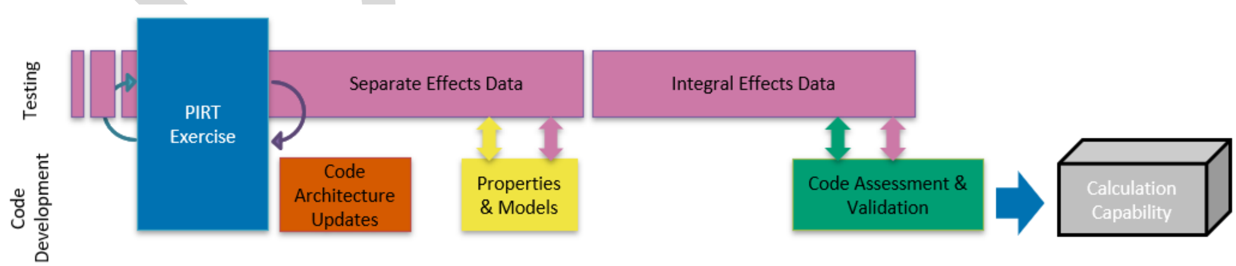

Figure 10.1 Development process for near -term calculation capability

Figure 10.1 shows that code development requires testing and data to feed model development and validation. Developing codes to demonstrate that ATF, higher burnup, and increased enrichment can be used safely includes updating codes with ATF, higher burnup, and increased enrichment material properties and models and then validating the updated codes against relevant experimental data. The validation exercise ensures that a code appropriately models key phenomena and accurately predicts the parameters of safety importance. The datasets used to develop models often come from separate effects testing (i.e. mechanical properties testing, autoclave testing), whereas code assessment and validation often use data generated in integral effects (i.e. irradiation campaigns, loss of coolant accident testing, reactivity-initiated-accident testing) test programs.

Much of the work to update the aforementioned codes for near-term ATF concepts has been completed. The NRC has sponsored two PIRTs to date, covering the behavior of chromium-coated zirconium-alloy cladding in-reactor operating and accident conditions (ADAMS Accession No. ML19172A154) and for the behavior of ATF in severe reactor accident conditions (ADAMS Accession No. ML21113A277). The NRC has also sponsored literature reviews have been completed to compile relevant information for the performance of ATF in reactor, transportation, and storage conditions; more information can be found on the NRC's public website. Furthermore, the NRC has updated the architecture of its codes to make them more flexible and to more easily implement new material property models. This means that once experimental data becomes available, the NRC can quickly add new models to the code. Again, the NRC is relying on the nuclear fuel vendors and on the U.S. Department of Energy to provide the data needed to implement new material properties and to validate the codes.

Although this plan addresses calculation capability development in four different disciplines, technical overlap between disciplines exists, including the introduction of new material properties. To reduce duplication of effort, the analysis tools will be coupled to allow codes to send and receive information between each other. For example, neutronics codes can be used to provide fuel performance codes with pellet radial power distribution information as a function of burnup, and fuel performance codes can provide neutronics codes with fuel temperature and deformation calculations. Thus, coupling the codes leverages information sharing to improve the overall analysis capabilities and ensures consistency across codes. Where possible, the NRC will coordinate with DOE to reduce duplication of effort in calculation capability development.

11 COMPLETED PREPARATORY ACTIVITIES

The NRC staff has completed many activities in preparation for ATF, higher burnup, and increased enrichment submittals. Additionally, the NRC is performing and has completed multiple reviews for ATF, higher burnup, and increased enrichment submittals. The complete list of these public activities can be found on the NRC's ATF public website:

https://www.nrc.gov/reactors/atf.html

The website contains the following collections of ongoing and completed activities:

- The ATF-related licensing actions page provides all submitted ATF, higher burnup, and increased enrichment licensing actions and the completed NRC review, if applicable. This page can be found at:

  https://www.nrc.gov/reactors/atf/licensing-actions.html

- The ATF-related documents page provides a listing of all NRC-issued public documents relevant to ATF, higher burnup, or increased enrichment subjects that are not reviews of industry submittals. This page can be found at:

  https://www.nrc.gov/reactors/atf/related-docs.html

- The public interactions page provides a listing of all public meetings held since April 2018 that are related to ATF, higher burnup, and increased enrichment. This page can be found at:

  https://www.nrc.gov/reactors/atf/public-interact.html

- The NRC staff has completed significant work regarding international cooperation and coordination. The completed and ongoing international work can be found on the ATF website international page, which can be found at:

  https://www.nrc.gov/reactors/atf/international-interact.html

12 PATH FORWARD

This Project Plan represents the high-level strategy to prepare the NRC for conducting efficient and effective reviews of ATF designs. The plan is intended to be a living document that may evolve as industry plans are refined and the state of knowledge for ATF concepts advances. The staff will develop concept-specific licensing roadmaps when necessary to clearly identify the regulatory criteria which must be satisfied for approval.

The staff's priority, now that this plan has been finalized, is to: 1) engage directly with the nuclear fuel vendors pursuing near-term ATF concepts, higher burnup, and increased enrichment with the objective of understanding the nexus between the phenomena identified as important to safety and their testing plans, and 2) understand the areas of margin recovery or operational flexibility that licensees plan to seek such that staff can begin to proactively refine the regulatory framework where necessary.

APPENDIX A: REGULATORY FRAMEWORK APPLICABILITY ASSESSMENT

As stated in Section 7 of the Project Plan, the NRC the staff determined the applicability of existing regulations and guidance for the near-term ATF concepts, higher burnup, and increased enrichment. Each regulation and guidance document listed in Appendix A was assessed for whether it was fully applicable to ATF, higher burnup, and increased enrichment. If a regulation or guidance was found to not be fully applicable, Table A.1 identifies this fact and provides a justification. However, the need for regulation or guidance to be fully applicable to ATF, higher burnup, and increased enrichment varies. In some instances, it is not, possibly because other regulations or guidance replace or supersede it. In other instances, it does need to be fully applicable. For some of these instances, NRC staff already discussed and agreed upon a path towards achieving full applicability for the relevant regulation or guidance, and Table A.1 will state these closure paths. In other instances, a closure path has not yet been agreed upon, and Table A.1 will indicate as such. Table A.1 also makes note of some pertinent requirements or actions that regulations or guidance require of an applicant to ensure the regulation or guidance is correctly applied.

Table A.1 is non-exhaustive and will be continually updated with each new version of the Project Plan as more information is developed. If/when advancements in an ATF concept not listed on Table A.1 demonstrate that the concept could obtain commercial viability, the staff will perform the analysis for that concept.

Table A.1 Key

Green: actions or requirements for NRC
Blue: information needs from industry
Fully applicable: indicates that the document can be applied to the concept
Not fully applicable: the document or parts of the document may not be applied to the concept, reasons for which are detailed below
MHA: maximum hypothetical accident
LOCA: loss of coolant accident
RIA: reactivity initiated accident
BU: burnup
FGR: fission gas release
FFRD: fuel fragmentation, relocation, and dispersal
IFBA: integral fuel burnable absorber
ID: inner diameter
HC PIE: hot cell post irradiation examination
RXA: recrystallized
ISG: interim staff guidance

Table A.1: REGULATORY FRAMEWORK APPLICABILITY ASSESSMENT

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
1	RG 1.183 AST Draft Revision 1 Analytical guidance for predicting dose	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
2	RG 1.183 AST Draft Revision 1 MHA / LOCA source terms	• Not fully applicable • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change MHA/LOCA source term and timing of releases Closure: Informal assistance request (IAR) out to RES to address this Priority: High (near-term)	• Not fully applicable • Reason: SAND-2011-0128 is not validated to 75 GWd/MTU Closure: Re-analysis of SAND-2011-0128 to higher BU is being conducted by RES and Sandia National Laboratory through 75 GWd/MTU Priority: Medium (Medium-term) • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change MHA/LOCA source term and timing of releases Closure: Informal assistance request (IAR) out to RES to address this Priority: High (near-term)	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
3	RG 1.183 AST Draft Revision 1 Non-LOCA steady-state and transient releases	• Not fully applicable • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change Non-LOCA steady state and transient source term Closure: Technical bases document in development to address this gap. Priority: High (near-term)	• Not fully applicable • Analytical procedure remains applicable • Tables 3 and 4 not applicable • Note: FAST is not validated up to 75 GWd/MTU. RES is working on the validation of FAST models to higher burnup. A data needs report has been issued from RES to examine what specifically is needed to expand the FAST capabilities to 75 GWd/MTU (medium-term priority). • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change source term Closure: Technical bases document in progress to address this gap. Priority: High (near-term) • Reason: Reactivity initiated accident (RIA) transient fission gas release	• Analytical procedure remains applicable • Tables 3 remains applicable • Note: With respect to Table 4, extent of ^{235}U enrichment in RIA empirical database unknown.	• Fully applicable • No data gaps	• Not fully applicable • Analytical procedure remains applicable • Tables 3 and 4 not applicable • Note: FAST is not validated for doped fuel. RES is working on validation of FAST models to doped fuel. A data needs report has been issued from RES to examine what specifically is needed to expand the FAST capabilities to doped pellets (medium-term priority). • Reason: RIA transient FGR for doped fuel has not been well quantified Closure: RIA transient FGR measurements on doped fuel are necessary

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
			(FGR) is not currently well quantified up to 75 GWd/MTU • Closure: RIA transient FGR measurements are necessary			
4	RG 1.195 Release fractions from TID-14844	• Not fully applicable • Reason: Validated only up to 62 GWd/MTU for non-LOCA accidents Closure: No closure necessary. Higher BU release fractions and source term to be addressed by RG 1.183 Rev. 1	• Not fully applicable • Reason: Validated only up to 62 GWd/MTU for non-LOCA accidents Closure: No closure necessary. Higher BU release fractions and source term to be addressed by RG 1.183 Rev. 1	• Fully applicable • No data gaps	• Not fully applicable • Reason: Non-LOCA accident release fractions are not validated for doped fuel pellets Closure: No closure necessary. Analytical procedure outlined in RG 1.183 Rev. 1 can be applied to doped fuel.	• Not fully applicable • Reason: Non-LOCA accident release fractions are not validated for doped fuel pellets Closure: No closure necessary. Analytical procedure outlined in RG 1.183 Rev. 1 can be applied to doped fuel.
5	RG 1.236 PWR Control Rod Ejection (CRE) and BWR Control Rod Drop (CRD) Accidents	• Fully applicable • No data gaps	• Not fully applicable • Note: Empirical database limited beyond 68 GWd/MTU. • Reason: FFRD as a result of HBU and possible loss of coolable geometry during RIA has not been well quantified or understood	• Not fully applicable • Reason: Stated applicability limited to 5.0 wt%. Increased enrichment will promote higher rod worth and peaking factors • Note: Extent of ^{235}U enrichment in RIA	• Not fully applicable • Reason: Stated applicability is limited to current LWR fuel rod designs • Note: Thin coating will not significantly alter fuel rod response. Cladding failure thresholds and damaged core	• Not fully applicable • Reason: Stated applicability is limited to current LWR fuel rod designs • Reason: doped fuel RIA performance has not been well quantified.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
			Closure: RIA data on high and increased burnup fuel rod segments with deposited energy beyond predicted cladding damage needed to investigate FFRD and loss of coolable geometry. Ideally, these data should also include transient FGR. • Reason: HBU effects on RIA not well quantified. HBU cladding failure thresholds should be defined. Closure: RIA data on high and increased burnup fuel rod segments, especially RXA cladding, with low corrosion needed to better understand burnup-effects and define cladding failure thresholds.	empirical database unknown.	coolability limits remain applicable. • No data gaps • Note: Guidance states that coated claddings will be addressed on a case-by-case basis	Closure: Data for irradiated, doped UO2 fuel pellets and IFBA fuel pellets needed to better understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD, transient FGR, and coolable geometry. • Note: Guidance states that doped pellets will be addressed on a case-by-case basis

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
6	10 CFR 50.46 LOCA Prescriptive Analytical Requirements	• Applicable* • Note: As written, it is fully applicable. The NRC staff has identified that recent research findings concerning burnup-effects are not addressed. Draft rule 50.46c addresses these burnup-effects • Note: Ideally, industry submittals should discuss the recent LOCA findings per NUREG/CR-7219.	• Applicable* • Note: As written, it is fully applicable. The NRC staff has identified that recent research findings concerning burnup-effects are not addressed. Draft rule 50.46c addresses these burnup-effects • Note: Ideally, industry submittals should discuss the recent LOCA findings per NUREG/CR-7219.	• Fully applicable	• Not fully applicable • Reason: As per 50.46(a)(1)(i), 50.46 is only applicable to zircaloy or ZIRLO cladded fuel. Closure: The staff still require that the prescriptive analytical requirements be met. Exemptions requests will have to be submitted. Refer to coated cladding ISG (ML19343A121).	• Not fully applicable • Reason: As per 50.46(a)(1)(i), 50.46 is only applicable to UO_2 fuel Closure: The staff still require that the prescriptive analytical requirements be met. Exemptions requests will have to be submitted and it should be demonstrated whether the prescriptive analytical limits are impacted by the proposed additive fuel concept.
7	LOCA Embrittlement Research Findings - Draft RG 1.222 - Draft RG 1.223 - Draft RG 1.224	• Fully applicable • Large population of fuel rods beyond threshold for cladding ID oxygen embrittlement.	• Fully applicable • Large population of fuel rods beyond threshold for cladding ID oxygen embrittlement.	• Fully applicable • No data gaps	• Fully applicable • Rate for oxidation and embrittlement different from bare zirconium • Note: Single sided steam oxidation data and subsequent mechanical data as well as double sided integral steam oxidation	• Fully applicable • Large population of fuel rods beyond threshold for cladding ID oxygen embrittlement • Note: Hot cell (HC) post irradiation examination (PIE) data needed to define threshold

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
					data and subsequent mechanical data are necessary to establish PQD limits.	for fuel-clad bond layer.
8	STS (STSB) B&W: Figure 3.7.16-1 4.2.1 4.3.1.1 4.3.1.2 Westinghouse: Figure 3.7.17-1 4.2.1 4.3.1.1 4.3.1.2 CE: Figure 3.7.18-1 4.2.1 4.3.1.1 4.3.1.2 GE: 4.2.1 4.3.1.1 4.3.1.2	• TS 4.2.1 and 4.3.1 are fully applicable • No data gaps • Figure 3.7.16-1, 3.7.17-1, and 3.7.18-1 are fully applicable • Note: Licensees should provide plant-specific figure for TS with LAR.	• TS 4.2.1 and 4.3.1 are fully applicable • No data gaps • Figure 3.7.16-1, 3.7.17-1, and 3.7.18-1 are applicable • Note: Licensees should provide plant-specific figure for TS with LAR.	• TS 4.2.1 is fully applicable pending the outcome of the following: • NRC and TSTF to discuss whether or not the term “slightly” in TS 4.2.1 includes fuels enriched beyond 5%	• TS 4.2.1 is fully applicable • Note: Licensees should revise TS 4.2.1 to specify chromium coated cladding.	• TS 4.2.1 is fully applicable • Note: Licensees should revise TS 4.2.1 to specify doped pellets.
9	10 CFR 50.67 Accident Source Term	Potential impacts to accident source term described above for RG 1.183 Revision 1.				
10	10 CFR 50.68 Criticality Accident Requirements	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Not fully applicable • Reason: 5 wt% enrichment limit	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				(without criticality monitoring system) explicitly stated Closure: Exemption requests and/or rulemaking to be conducted Priority: High • Note: Alternatively, licensees can adopt 70.24 • Note: Criticality analyses may need to be updated.		
11	10 CFR 50 Appendix K: ECCS Evaluation Models	• Not fully applicable • Reason: Appendix K is not fully applicable to the current BU limit of 62 GWd/MTU. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: TBD • Reason: FFRD is not addressed	• Not fully applicable • Reason: Appendix K is not fully applicable to the current BU limit of 62 GWd/MTU. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: TBD • Reason: FFRD is not addressed	• Fully applicable • No data gaps	• Not fully applicable • Reason: The Baker-Just metal-water reaction rate correlation is not applicable to coated cladding, as it was developed for bare zircaloy cladding Closure: An oxidation kinetics model based on chrome-coated cladding should be developed. If the benefits of the coating are not to be realized and the Baker-Just correlation is used, it should be	• Fully applicable • No data gaps

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		Closure: FFRD should be addressed in LOCA evaluation methodologies. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a technical justification for when the effect of fragmentation induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant.	Closure: FFRD should be addressed in LOCA evaluation methodologies. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a technical justification for when the effect of fragmentation induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant.		demonstrated that it bounds the coated cladding oxidation kinetics. • Note: Coated cladding may have an impact on thermal-hydraulics, e.g., changes in wettability and hydraulic diameter can affect the critical heat flux/critical power correlation. Although Thermal-hydraulic impact of coated cladding is expected to be minimal, this should be justified to confirm the continued applicability of thermal-hydraulic models.	

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
12	10 CFR 51.21 Environmental Assessment (EA) vs 51.22 Categorical Exclusion (CATEX) (NMSS)	• Fully applicable • CATEXs are for categories of actions whose potential for significant environmental impacts are so minimal that any consideration or documentation of environmental impacts are not needed. The changes to LWR fuel for the conditions in these three columns are above what has been previously analyzed for environmental impacts (i.e., 10 CFR 51.52, Environmental effects of transportation of fuel and waste - Table S-4, see below). • It is premature to decide now to apply a CATEX due to the range of different ATF technologies and our uncertainty about what the industry will submit. Given this situation and to reduce litigative risk, recommendation is to perform an EA for the first licensing action of a given type of ATF design and then use this EA as a basis for future similar actions (e.g., CATEX).			• Fully applicable • <u>Note</u>: Due to plant changes and unanalyzed environmental impacts (i.e., effluent releases, accidents, and transportation of fuel and waste) as a result of increased enrichment and higher burnup levels, it is expected that an EA should be performed (NRC and/or industry) in the first LAR application for this ATF type.	• Fully applicable • <u>Note</u>: Due to plant changes and unanalyzed environmental impacts (i.e., effluent releases, accidents, and transportation of fuel and waste) as a result of increased enrichment and higher burnup levels, it is expected that an EA should be performed (NRC and/or industry) in the first LAR application for this ATF type.
13	10 CFR 51.51, Uranium fuel cycle environmental data – Table S-3 (NMSS)	• Fully applicable • Several aspects of the uranium fuel cycle are expected to remain unchanged from current processes (e.g., uranium recovery and conversion). • <u>Note:</u> Prior to the submittal of an ATF LAR from a nuclear power plant licensee, the appropriate changes to the fuel cycle facilities will have to be in place with appropriate NRC approval. Examples include changes to the National Enrichment Facility's license to enrich to the levels specified by ATF fabricators/vendors and whether existing fuel fabricators can manufacture the fuel assemblies under their existing license or need appropriate LARs approved by the NRC. Thus, at the time of an ATF LAR from a nuclear power plant licensee, these associated fuel cycle impacts will be known and that prior NEPA analysis can be incorporated by reference into the LAR NEPA review. • <u>Note</u>: an evaluation of whether the spent ATF could be covered by the Continued Storage GEIS (NUREG-2157 [ML14196A105 and ML14196A107]) and 10 CFR 51.23 would need to be assessed at the time of the ATF LAR. This assessment of spent ATF storage would involve whether the spent ATF has the same or very similar external impacts as the LWR spent fuel analyzed in the Continued Storage GEIS. The staff might be able to perform a preliminary environmental study based on the certificate of compliance applications expected in order to have relevant storage casks pre-approved for the storage of spent ATFs.				

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
14	10 CFR 51.52, Environmental effects of transportation of fuel and waste - Table S-4 (NMSS)	• Fully applicable • Note: The proposed enrichment and burnup levels are beyond the conditions specified in 10 CFR 51.52(a) and analyzed in the License Renewal GEIS (NUREG-1437 Revision 1). The staff would need to assess the impacts by conducting a full description and detailed analysis of the environmental effects of transportation of fuel and waste to and from the reactor, including values for the conditions of transport and for the environmental risks from accidents in transport (see 10 CFR 51.52(b)). • Note: NUREG/CR-6703 (ML010310298) did attempt to analyze burnup levels greater than 62 GWd/MTU but found there was too much uncertainty in changes in the gap-release fraction associated with increasing fuel burnup. This study recommends that this be re-evaluated as the methods for assessing fission gas releases are validated with data for higher burnups (see page 52 of NUREG/CR-6703). If resources are available, the staff could perform an analysis of the transportation impacts based on aspects of NUREG/CR-6703 for burnup levels up to 80 GWd/MTU if appropriate gap-release fractions and subsequent transportation package release fractions are available for use.				
15	10 CFR 70.24 Criticality Accident Requirements	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: This regulation represents an alternative to 50.68: licensees can install criticality monitoring systems rather than meeting the requirements set forth in 50.68(b) • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
16	NUREG-0630 Cladding Swelling and Rupture Models for LOCA Analysis	• Not fully applicable • Reason: NUREG-0630 models are hot-rod models and thus do not consider interactions between rods. Interactions between rods affect swelling and rupture behavior, which will impact the amount of fragmented fuel that may disperse,	• Not fully applicable • Reason: NUREG-0630 models are hot-rod models and thus do not consider interactions between rods. Interactions between rods affect swelling and rupture behavior, which will impact the amount of fragmented fuel that may disperse,	• Fully applicable • No data gaps	• Not fully applicable • Reason: Cladding swelling and burst data presented is from bare zircaloy cladding, so should not be used if the benefits of coated cladding are to be realized. Closure: As stated in coated cladding ISG (ML19343A121), if	• Fully applicable • No data gaps

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		so should not be neglected. Closure: Interactions between rods should be considered for swelling and rupture modelling. • Reason: HBU rod internal pressures may exceed the rod internal pressures of the data provided in NUREG-0630 Closure: If the NUREG-0630 data is desired to be used, it should be shown that HBU rod internal pressures are bounded by the data provided in NUREG-0630.	so should not be neglected. Closure: Interactions between rods should be considered for swelling and rupture modelling. • Reason: HBU rod internal pressures may exceed the rod internal pressures of the data provided in NUREG-0630 Closure: If the NUREG-0630 data is desired to be used, it should be shown that HBU rod internal pressures are bounded by the data provided in NUREG-0630.		NUREG-0630 is used, it would be useful to show that data bounds the performance of the coated cladding, or if new burst stress and ballooning strain limits are proposed, a significant body of data would be useful to demonstrate that the degree of swelling will not be underestimated. • Framework / approach described for modeling swelling and rupture remains fully applicable.	
17	NUREG-0800 SRP Chapter 4.2 Fuel System Design	• Not fully applicable • Reason: Interim RIA guidance provided in Appendix B does not match the most recent guidance given in RG 1.236. Closure: Appendix B should be updated or removed, and readers should be directed to RG 1.236.	• Not fully applicable • Reason: Interim RIA guidance provided in Appendix B does not match the most recent guidance given in RG 1.236. Closure: Appendix B should be updated or removed, and readers should be directed to RG 1.236. Note that	• Not fully applicable • Reason: Interim RIA guidance in Appendix B does not match the current RIA guidance in RG 1.236. RG 1.236 is also not applicable to fuel enriched to greater than 5.0 wt.%.	• Not fully applicable • Note: Coated cladding interim staff guidance (ISG) (ML19343A121) created to supplement SRP Section 4.2 in coated cladding reviews. • Reason: Interim RIA guidance in Appendix B does	• Not fully applicable • Reason: Interim RIA guidance in Appendix B does not match the current RIA guidance in RG 1.236. RG 1.236 is also not applicable to doped fuel.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		Priority: Low (this is administrative in nature as RG 1.236 has been published to address RIA guidance up to 68 GWd/MTU) • Reason: FFRD not thoroughly addressed. Closure: Potential addition of vendor requirements for submittals where rod burst is assumed to occur. Priority: TBD	RG 1.236 is not fully applicable to 75 GWd/MTU. Priority: Low • Reason: FFRD not thoroughly addressed. Closure: Potential addition of vendor requirements for submittals if rod burst is assumed to occur. Priority: TBD	Closure: See discussion on RG 1.236 • Note: Increased enrichment will promote higher rod worth and peaking factors and thus fuel enthalpy rise during RIAs.	not match the current RIA guidance in RG 1.236. Note that RG 1.236 is also not applicable to coated cladding. Closure: See discussion on RG 1.236 and coated cladding ISG (ML19343A121).	Closure: See discussion on RG 1.236 • Reason: Impact of additives on fuel performance has not been extensively quantified. Closure: Data on irradiated, doped UO2 fuel pellets and IFBA fuel pellets needed to better understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD, transient FGR, and coolable geometry
18	NUREG-1465 Accident Source Terms for Light Water Reactor Nuclear Power Plants	Potential impacts to accident source term described above for RG 1.183 Revision 1.				

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
19	NUREG-2121 FFRD During LOCA	• Not fully applicable • Reason: Published in 2012, so does not include recent FFRD research findings Closure: Recent FFRD research findings to be covered in a research information letter (RIL) Priority: High (near-term) • Note: Halden tests described in the NUREG include several tests at > 75 GWd/MTU • Note: Studsvick tests described in the NUREG include several tests at > 70 GWd/MTU • Note: More data is needed from industry to properly address FFRD if the burst is predicted to occur. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a	• Not fully applicable • Reason: Published in 2012, so does not include recent FFRD research findings Closure: Recent FFRD research findings to be covered in a research information letter (RIL) Priority: High (near-term) • Note: Halden tests described in the NUREG include several tests at > 75 GWd/MTU • Note: Studsvick tests described in the NUREG include several tests at > 70 GWd/MTU Note: More data is needed from industry to properly address FFRD if burst is predicted to occur. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a	• Not fully applicable • Note: The effect of enrichment on FFRD phenomena was not a part of NUREG-2121 • Note: INL Power Burst Facility tests included fuel enriched to 9.6 wt%. • Reason: The effect of enrichment with regard to FFRD during a LOCA has not been well quantified. Closure: TBD. The effect of enrichment with regards to FFRD during a LOCA should be determined.	• Fully applicable • Note: Only uncoated cladding considered in tests described in the NUREG. • Note: Swelling and burst data are needed to needed to show that NUREG-0630 bounds the performance of the coated cladding, or if new burst stress and ballooning strain limits are proposed, a significant body of data would be useful to demonstrate that the degree of swelling will not be underestimated.	• Not fully applicable • Reason: Only traditional UO_2 fuel considered in the tests described in the NUREG. Impact of additives on fuel performance has not been extensively quantified. Closure: Data for irradiated, doped UO2 fuel pellets and IFBA fuel pellets needed to better understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD, transient FGR, and coolable geometry.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		technical justification for when the effect of fragmentation induced FGR is to be considered. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant.	technical justification for when the effect of fragmentation induced FGR is to be considered. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant.			
20	NUREG/CR-7219 Cladding Behavior During Postulated LOCA	• Fully applicable • No data gaps	• Fully applicable • Note: Section 3.3.2 details "current" PQD results for only up to 70 GWd/MTU	• Fully applicable • No data gaps	• Not fully applicable • Reason: Data only included bare zirconium. Rate of oxidation and embrittlement will be different Closure: TBD (likely not necessary) • Conclusions remain applicable • Note: Single sided steam oxidation data and subsequent mechanical data as well as double sided integral steam oxidation	• Fully Applicable • Large population of fuel rods beyond threshold for cladding ID oxygen embrittlement • Reason: BU threshold for the formation of fuel-clad bond layer has not been well quantified in doped fuel. Closure: Hot cell (HC) post irradiation examination (PIE) needed to define

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
					data and subsequent mechanical data are necessary to establish PQD limits	threshold for fuel-clad bond layer
21	RG 1.157 Best-Estimate Calculations of ECCS Performance	• Not fully applicable • Reason: RG 1.157 is not fully applicable to the current BU limit of 62 GWd/MTU. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: The staff has been aware of issues such as TCD for some time and plans to update RG 1.157 in the coming years. Priority: Medium • Reason: FFRD is not addressed Closure: FFRD should be addressed in LOCA evaluation	• Not fully applicable • Reason: RG 1.157 is not fully applicable to the current BU limit of 62 GWd/MTU. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: The staff has been aware of issues such as TCD for some time and plans to update RG 1.157 in the coming years. Priority: Medium • Reason: FFRD is not addressed Closure: FFRD should be addressed in LOCA evaluation	• Fully applicable • No data gaps	• Not fully applicable • Reason: Cathcart-Pawel correlation and associated data is referenced as acceptable for calculating the rates of energy release, hydrogen generation, and cladding oxidation, but was for a developed for bare zircaloy cladding. Use of the Cathcart-Pawel correlation would not realistically model oxidation kinetics. Chrome coated cladding is expected to have better oxidation performance than bare zirconium cladding. Closure: An oxidation kinetics model based on chrome-coated cladding should be developed. If the	• Not fully applicable • Reason: Section 3.2.1 on initial stored energy in the fuel is out of date. It also references an acceptable initial stored energy model. This model was developed for UO_2 and is not acceptable currently for UO_2 or doped fuel. Closure: It should be shown that the stored energy does not change much from a vendor's current UO_2 models, or new models should be proposed. • Note: this RG provides a means of meeting the 50.46 prescriptive analytical

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		methodologies. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a technical justification for when the effect of fragmentation induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant. • <u>Reason</u>: The limiting rod may not be the hot rod when considering swelling and rupture (see NUREG-0630 discussion)	methodologies. If burst and thus FFRD is expected to occur, technical justification for burnup threshold for which FFRD is to be considered is needed, as well as a technical justification for when the effect of fragmentation induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, the impact of fuel particle transport and deposition on coolability and criticality should be examined, including addressing potential sump blockage caused by fuel particles in the coolant. • <u>Reason</u>: The limiting rod may not be the hot rod when considering swelling and rupture (see NUREG-0630 discussion)		benefits of the coating are not to be realized and the Cathcart-Pawel correlation is used, it should be demonstrated that it bounds the coated cladding oxidation kinetics. • <u>Note</u>: this RG provides a means of meeting the 50.46 prescriptive analytical requirements; those requirements are not applicable for doped pellets due to the wording of 50.46(a)(1)(i), so this RG is only *fully* applicable pending an accepted exemption to 50.46.	requirements; those requirements are not applicable for doped pellets due to the wording of 50.46(a)(1)(i), so this RG is only *fully* applicable pending an accepted exemption to 50.46.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		Closure: rod to rod interactions should be considered for swelling and rupture in LOCA analyses	Closure: rod to rod interactions should be considered for swelling and rupture in LOCA analyses			
22	RG 1.203 Transient and Accident Analysis Methods	• Fully applicable • Note: Vendors will need to validate their evaluation models to higher BU.	• Fully applicable • Note: Vendors will need to validate their evaluation models to higher BU.	• Fully applicable • Note: Vendors will need to validate their evaluation models to higher enrichments	• Fully applicable • Note: 50.46 requirements are discussed, so this RG is only *fully* applicable pending an accepted exemption to 50.46. See discussion on 50.46 for more details. • Note: Vendors will need to update and validate their evaluation models to consider coated cladding	• Fully applicable • Note: 50.46 requirements are discussed, so this RG is only *fully* applicable pending an accepted exemption to 50.46. See discussion on 50.46 for more details. • Note: Vendors will need to update and validate their evaluation models to consider doped fuel
23	RG 1.240 Fresh and Spent Fuel Pool Criticality Analysis NEI 12-16, Rev. 4	• Not fully Applicable • Reason: Cites use of gap release fractions from RG 1.183 and PNNL-18212 Rev 1. RG 1.183 Rev 0 is only applicable up to 62 GWd/MTU and PNNL-18212 Rev 1 is only applicable up to 65 GWd/MTU.	• Not fully applicable • Reason: Cites use of gap release fractions from RG 1.183 and PNNL-18212 Rev 1. RG 1.183 Rev 0 is only applicable up to 62 GWd/MTU and PNNL-18212 Rev 1 is only applicable up to 65 GWd/MTU.	• Not fully applicable • Reason: Mentions gap release fractions from RG 1.183 Rev. 0, which is not fully applicable. Rev. 1 of that document is not fully applicable, but the analytical procedure remains applicable.	• Fully applicable • No data gaps	• Not fully applicable • Reason: Mentions gap release fractions from RG 1.183 Rev. 0, which is not fully applicable. Rev. 1 of that document is not fully applicable, but the analytical procedure

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		Closure: Will be fully applicable upon the publication of RG 1.183 Rev 1, which will provide tables for gap release fractions	Closure: Will be fully applicable upon the publication of RG 1.183 Rev 1, which will provide an analytical procedure for calculating gap release fractions that is applicable.	Closure: Will be fully applicable upon the publication of RG 1.183 Rev 1, which will provide an analytical procedure for calculating gap release fractions that is applicable. • Note: Criticality codes must be validated with experiments that cover the applicable enrichment range • Note: Criticality analyses will need to be updated to show adherence to the k-effective regulatory limits.		remains applicable. • Closure: RG 1.183 Rev 1, will provide an analytical procedure for calculating gap release fractions that is applicable. • Note: Section 9.3 of NEI 12-16 Rev. 4 describes how to approach new fuel designs. • Note: If dopant increases density, higher density fuel may lead to more ^{235}U in the spent fuel pool • Note: Experiments for validation of criticality codes may be necessary. • Note: RG 1.240 Section C paragraph o states that for new fuel designs, justification for continued use of the assumptions presented in NEI 12-16 Rev 4 may be necessary.

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#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
24	NUREG-0800 (SRP 9.1.1) Criticality Safety of Fresh and Spent Fuel Storage and Handling	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: Compliance with 10 CFR 50.68 is a part of the stated review procedures. • Note: Criticality analyses will need to be updated to show adherence to the k-effective regulatory limits.	• Fully applicable • No data gaps	• Fully applicable • Note: Experiments for validation of criticality codes may be necessary.
25	NUREG-0800 (SRP 9.1.2) New and Spent Fuel Storage	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: Compliance with 10 CFR 50.68 is a part of the stated review procedures.	• Fully applicable • No data gaps	• Fully applicable • Note: Higher density fuel may lead to more ^{235}U in the spent fuel pool; experiments for validation of criticality codes may be necessary.
26	NUREG-1520 (Fuel Cycle SRP) - NMSS	• Not applicable • Reason: HBU is not applicable to the fuel fabrication. Closure: No closure necessary	• Not applicable • Reason: HBU is not applicable to the fuel fabrication. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
27	NUREG-1065 Material Control and Accounting (MC&A) for LEU fuel fabrication	• Not applicable • Reason: HBU is not applicable to the fuel fabrication. Closure: No closure necessary	• Not applicable • Reason: HBU is not applicable to the fuel fabrication. Closure: No closure necessary.	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
28	NUREG/CR-5734 MC&A for enrichment facilities	• Not applicable	• Not applicable	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		• Reason: HBU is not applicable to the fuel enrichment. Closure: No closure necessary.	• Reason: HBU is not applicable to the fuel fabrication. Closure: No closure necessary.			
29	NUREG-2214, Managing Aging Processes in Storage (MAPS) Report - NMSS	• Not fully applicable • Reason: The evaluations of aging-related degradation of spent fuel cladding need to be extended to HBU. HBU may influence which aging mechanisms are credible during extended storage and may warrant unique recommended preventive actions (e.g., fuel drying criteria) and other aging management approaches. Closure: Fuel performance modeling and characterization of irradiated cladding with higher BU (e.g., mechanical testing, microstructure characterization) to assess credible aging mechanisms.		• Not fully applicable • Reason: Increased use of burnable absorbers may affect cladding hoop stresses and the associated aging-related phenomena. Closure: Fuel performance modeling and characterization of irradiated cladding with increased enrichment (e.g., mechanical testing) to assess credible aging mechanisms.	• Not fully applicable • Reason: The evaluations of aging-related degradation of spent fuel cladding do not consider the potential effects of Cr coating. Closure: Characterization of irradiated Cr-coated cladding (e.g., mechanical testing, microstructure analysis) to assess credible aging mechanisms, such as hydrogen effects, thermal creep, and corrosion.	• Not fully applicable • Reason: Doped fuel pellets may affect cladding hoop stresses (via pellet-clad interactions or fission gas release) and the associated aging-related phenomena Closure: Fuel performance modeling and characterization of irradiated cladding with doped pellets (e.g., mechanical testing) to assess credible aging mechanisms.
30	NUREG-2215, Standard Review Plan for Spent Fuel Dry Storage - NMSS	• Not fully applicable • Reason: Guidance provides is limited to burnups up 60 GWd/MTU. Closure: TBD • Note: Shielding discussion will need to consider high burnups and fuel composition to account for increase source term. Literature reviews and research will provide information on this technical issue.		• Not fully applicable • Reason: Guidance is limited to enrichments up to 5%. Closure: TBD • Note: Shielding discussion will need to consider higher enrichments to	• Under review • Note: Guidance provides information on Zr alloy cladding. No discussion of unique considerations for Cr coated on cladding	• Under review • Note: Staff is evaluating the need to address potential validation variations and effect on fuel density due to fuel dopants.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		• Note: Criticality discussion will need to consider higher burnups as well as validation and address bounding profiles for higher burnup fuels. Literature reviews and research will provide information on this technical issue. • Note: Materials evaluation will need to consider higher burnups effect on cladding performance. Staff will assess this impact when lead test assembly's data becomes available.		account for increase burnable absorber use and impact on source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion will need to consider higher enrichment as well as validation and address bounding profiles for higher enrichment fuels . Literature reviews and research will provide information on this technical issue. • Note: Materials discussion will need to consider if an increase in burnable absorber use may affect cladding hoop stress and, consequently, the recommended fuel drying criteria. Applicant could also provide information to	performance. Staff will assess this impact when lead test assembly's data becomes available. Applicant could also provide this information.	• Note: Guidance provides information on Zr alloy cladding. No discussion of unique considerations for fuel dopants on fuel performance. Staff will assess this impact when lead test assembly's data becomes available. Applicant could also provide this information.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				support the evaluation.		
31	NUREG-2216, Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material	• Not fully applicable • Reason: Guidance provided is limited to burnups up 60 GWd/MTU. Closure: TBD • Note: Shielding discussion will need to consider high burnups and fuel composition to account for increase source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion will need to consider higher burnups as well as validation and address bounding profiles for higher burnup fuels. Literature reviews and research will provide information on this technical issue. • Note: Materials evaluation will need to consider higher burnups effect on cladding performance. Staff will assess this impact when lead test assembly's data becomes available.		• Not fully applicable • Reason: Guidance is limited to enrichments up to 5%. Closure: TBD • Note: Shielding discussion will need to higher enrichments to account for increase burnable absorber use and impact on source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion will need to consider higher enrichments as well as validation and additional isotopic depletion, and bounding profiles. Literature reviews and research will provide information on this technical issue. • Note: Materials discussion will need	• Under review • Note: Guidance provides information on Zr alloy cladding. No discussion of unique considerations for Cr coated on cladding performance. Staff will assess this impact when lead test assembly's data becomes available. Applicant could also provide this information.	• Under review • Note: Staff is evaluating the need to address potential validation variations and effect on fuel density due to fuel dopants. • Note: Guidance provides information on Zr alloy cladding. No discussion of unique considerations for fuel dopants on fuel performance. Staff will assess this impact when lead test assembly's data becomes available. Applicant could also provide this information.

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				to consider if an increase in burnable absorber use may affect cladding hoop stress and, consequently, the recommended fuel drying criteria		
32	NUREG-2224, Dry Storage and Transportation of High Burnup	• Not fully applicable • Reason: The evaluations of fuel cladding performance and recommended licensing approaches need to be extended to higher BU. Increased BU may influence cladding internal pressure, mechanical properties, and the credible aging mechanisms during extended storage. Increased BU may also warrant revised recommended fuel drying practices to maximize cladding performance. Closure: Fuel performance modeling and characterization of irradiated cladding with higher BU (e.g., mechanical testing, microstructure characterization)		• Not fully applicable • Reason: Increased use of burnable absorbers may affect cladding hoop stresses and the associated cladding behavior. Closure: Fuel performance modeling and characterization of irradiated cladding with increased enrichment (e.g., mechanical testing)	• Not fully applicable • Reason: The evaluations of fuel cladding performance do not consider the potential effects of Cr coating (e.g., cladding oxidation, hydrogen pickup). Revised fuel drying criteria to consider effects of reduced hydrogen pickup in the reactor may be warranted. Closure: Characterization of irradiated Cr-coated cladding (e.g., mechanical testing, microstructure analysis)	• Not fully applicable • Reason: Doped fuel pellets may affect cladding hoop stresses (via pellet-clad interactions or fission gas release) and the associated cladding performance Closure: Fuel performance modeling and characterization of irradiated cladding with doped pellets (e.g., mechanical testing)

#	Regulatory Guide or Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chrome-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
33	RG 3.48 “Standard Format and Content for the Safety Analysis Report for An ISFSI” (NMSS)	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
34	RG 7.9, Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material” (NMSS)	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
35	RG 3.71, “Nuclear Criticality Safety Standards for Nuclear Materials Outside Reactor Cores” (NMSS)	• Not applicable • Reason: HBU is not applicable to the fuel enrichment or fabrication. Closure: No closure necessary	• Not applicable • Reason: HBU is not applicable to the fuel enrichment or fabrication. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
36	RG 3.67/ Emergency Preparedness	• Not applicable • Reason: HBU is not applicable to the fuel enrichment or fabrication. Closure: No closure necessary	• Not applicable • Reason: HBU is not applicable to the fuel enrichment or fabrication. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

APPENDIX B: LICENSING PATHWAYS

The U.S. Nuclear Regulatory Commission (NRC) staff has developed “licensing pathways” to depict the remaining informational needs or tasks that should be completed in order to efficiently review accident-tolerant fuel (ATF) topical reports and plant-specific license amendment requests.

These two pathways, shown in Figures B.1-1 and B.1-2, are a simple depiction of the “closure” items identified in the Regulatory Framework Applicability Assessment table in Appendix A for higher burnup fuel.

Following the same color scheme from the Regulatory Framework Applicability Assessment table, green colored boxes are items to be addressed by NRC staff and blue colored boxes are items to be addressed by a fuel vendor or a licensee. This is also illustrated by items above the horizontal line (NRC actions) and below the horizontal line (fuel vendor or licensee information needs).

Boxes with hashed shading are related to the environmental review. Boxes that are linked by dashed arrows indicate a relationship—if not addressed by the NRC, then it should be evaluated by the fuel vendor or considered by the licensee during the review of the license amendment request.

Items to the left of the vertical line are actions or information needs that ideally should be completed prior to the submittal of plant-specific license amendment requests (LARs). This will ensure an efficient review of LARs. If such items are not completed prior to the submittal of a LAR, then schedule risk may increase.

The lone blue colored box with a dashed border is specific to licensees that have not yet adopted an alternate source term of non-loss-of-coolant accidents.

Lastly, the dashed border around the Advisory Committee on Reactor Safeguards (ACRS) Review box on the plant-specific LAR review pathway indicates the possibility of an ACRS review.

Pathways for other ATF concepts are under development and will be added to this appendix in a future revision.

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B.1: Higher Burnup Licensing Pathways

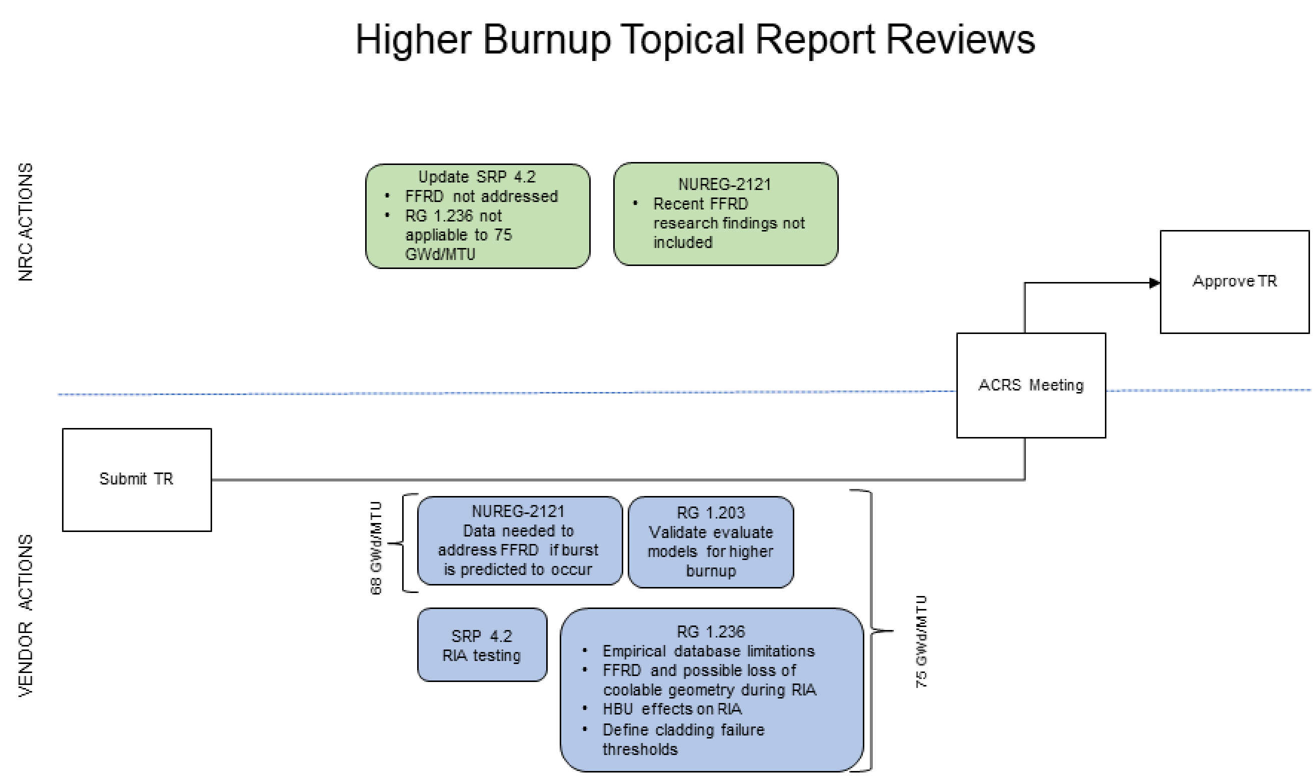

Figure B.1-1 Higher Burnup Topical Report Reviews

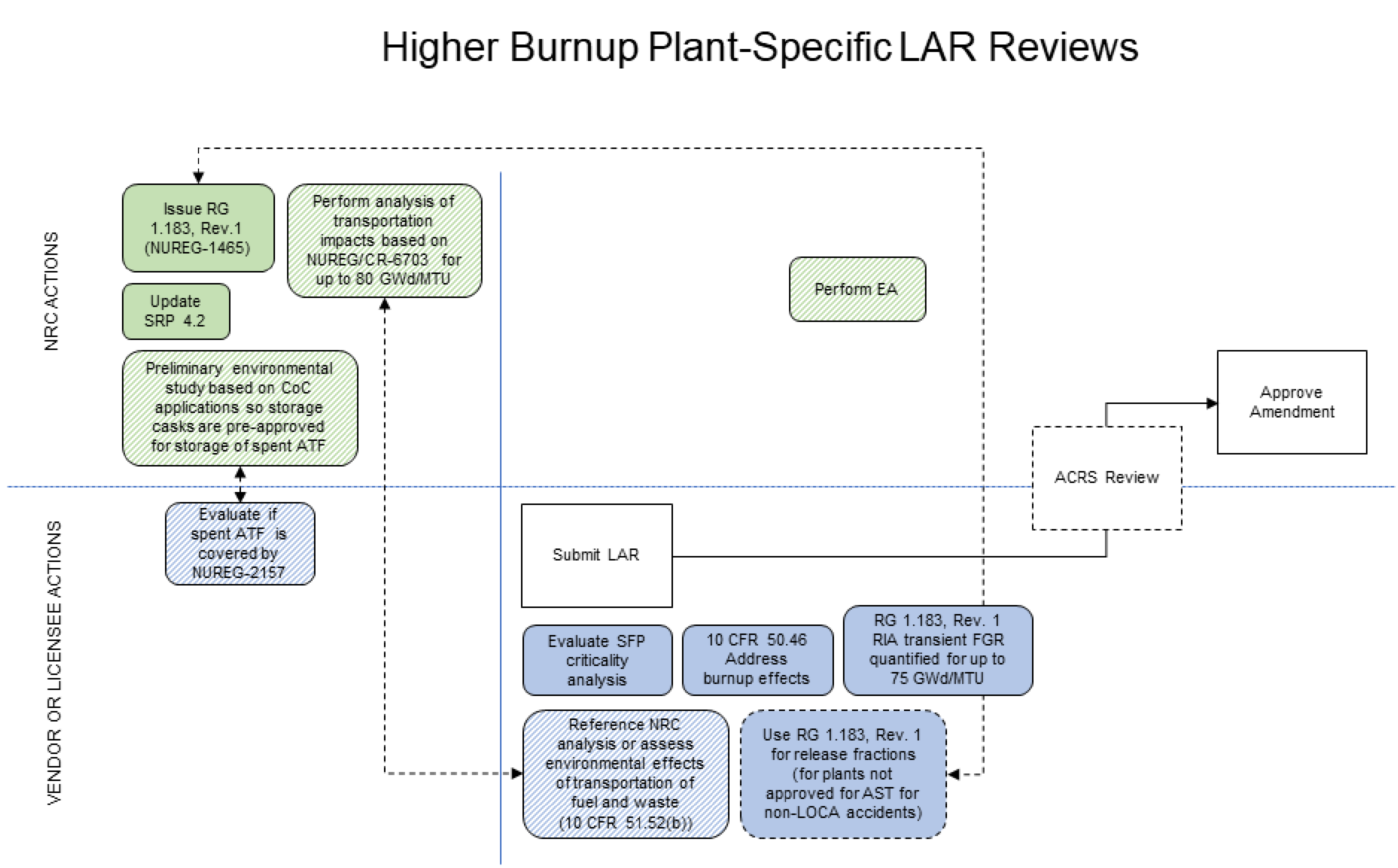

Figure B.1-2 Higher Burnup Plant-Specific LAR Reviews

APPENDIX C: CHANGE HISTORY

ITEM	LOCATION	REVISION	DESCRIPTION
1	Page 5, Section 2, Figure 2.1	1.1	ATF Steering Committee figure updated to reflect Office merger related changes.
2	Page 7, Section 3, Table 3.1	1.1	ATF Milestone Schedule table updated.
3	Page 13, Section 3.4.3	1.1	Section updated to reflect completed PIRT actions.
4	Page 25, Section 7.2	1.1	LTA section updated to identify agency position letter.
5	Page 25, Section 7.4, Table 7.4	1.1	Basic edits made to the table.
6	Appendix A	1.1	New Appendix A added: “Fuel Burnup and Enrichment Extension Preparation Strategy.” Minor edits also made throughout document to capture the Appendix referencing.
7	Appendix B	1.1	Previous Appendix A moved to Appendix B. Minor editorial changes throughout.
8	Appendix C	1.1	New Appendix C added to capture document change history.
9	Appendix A	1.2	Previous Appendix A was re-incorporated into the main body of the project plan and replaced with the Regulatory Framework Applicably Analysis as a new Appendix A for in-reactor and fuel cycle, transportation, and storage.
10	Appendix B	1.2	Replaced Appendix B in its entirety with licensing pathway diagrams.