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 make NRC-regulated facilities safer. The U.S. nuclear industry, assisted by 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 standard of 5 weight percent uranium (U)-235 in the operating fleet on an aggressive timeline (by the mid-2020s). The NRC's preparation strategy and the new paradigm for fuel licensing outlined in this project plan is intended to support that timeline while still providing reasonable assurance of public health and safety at U.S. nuclear facilities and installations. As part of the new paradigm, the NRC staff evaluated the regulatory framework and determined it is capable of reviewing near-term ATF technologies (coated cladding, doped pellets, FeCrAl cladding), increased enrichment, and higher burnup without changes to the current regulations and guidance through the use of existing processes, including exemptions. However, the staff is gathering additional information, revising confirmatory codes, assessing the need to update guidance, and evaluating whether rulemaking would support the more efficient review of these applications. Given the evolving nature of new ATF technologies, the NRC understands that it may face challenges in its preparations and in technical and licensing reviews, but it is committed to working through such challenges thoughtfully and deliberately, consistent with the Principles of Good Regulation.

The NRC staff has developed the plan described in this document to increase regulatory stability and certainty, enhance and optimize NRC review, and manage the enterprise risk associated by increasing the likelihood of meeting the requested schedules (i.e., schedule risk). The plan includes a new paradigm for the licensing of ATF, higher burnup, and increased enrichment. In the staff's view, adherence to this strategy will allow the staff to expeditiously review applications for ATF designs, higher burnup, and increased enrichment while also ensuring adequate protection of public health and safety.

The NRC staff has engaged with its stakeholders to develop and finalize each version of the project plan, consistent with the NRC's principles of good regulation and with statutory requirements. For Version 1.2, the staff has held one public meeting with external stakeholders. The meeting summary is available in the Agencywide Documents Access and Management System (ADAMS) at Accession No. ML21208A146. The staff found this interaction invaluable and has considered the views and comments of the NRC's stakeholders in finalizing Version 1.2 of the ATF Project Plan.

The project plan describes the staff's high-level strategy for ensuring that it is ready to review ATF, higher burnup, and increased enrichment topical reports (TRs) and licensing actions for

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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.

the entire nuclear fuel cycle within the schedules requested by the industry. At this point, the strategy is concept and technology independent. An ATF "concept" is 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, and metallic fuels. Individual vendors may implement variations within each concept as specific technologies.

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 the DOE, several fuel vendors have announced plans to develop and seek approval for 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 developing 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 (replacing the uranium silicide (U_3Si_2) pellets previously under development), and metallic fuels (e.g., Lightbridge).

For the purposes of this plan, ATF concepts are broadly categorized as near term and longer term. "Near term" and "longer term" are often terms of convenience indicating the current expected deployment timeframe. Near-term ATF concepts are those for which the agency can largely rely on existing data, models, and methods for its safety evaluations. 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; it has not yet provided the NRC with licensing or deployment dates for FeCrAl. Longer term ATF concepts are those for which substantial new data, models, and methods are needed before the NRC staff can make a finding in a safety evaluation. UN fuel, metallic fuel, and SiC-based cladding are the current longer term ATF concepts. The industry has not yet provided the NRC with potential licensing and deployment dates for the longer-term technologies.

Based on stakeholder interactions, the NRC staff is aware that the industry plans to request higher fuel burnup limits along with the deployment of near-term ATF concepts. The staff expects requests to increase fuel burnup limits up to approximately 75 gigawatt-days per metric ton of uranium (GWd/MTU) rod-average (or equivalent). To achieve these burnups, the industry will also need to request increases in fuel enrichment from the current standard of 5 weight percent U-235 up to approximately 10 weight percent U-235. The industry has labeled enrichments up to 10 weight percent U-235 as low-enriched uranium plus (LEU+).[2] Additionally, on January 14, 2019, President Trump signed the Nuclear Energy Innovation and Modernization Act (NEIMA). NEIMA Section 107, "Commission Report on Accident Tolerant Fuel," describes 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. Because of the economic link between ATF technologies, higher burnup, and increased enrichment, in light of the NEIMA definition, the NRC staff considers the pursuit of higher burnup and increased enrichment a component of the ATF program.

This project plan covers the complete fuel cycle, including the front end (i.e., enrichment, fuel fabrication, and fresh fuel transportation) and the back end (i.e., spent fuel transportation and storage), and outlines the NRC's strategy for preparing to license ATF designs, higher burnup, and increased enrichment. This plan only briefly touches on existing licensing activities, such as the TR process, the implementation of lead test assembly (LTA) programs, the license amendment request (LAR) process, and front-end and back-end licensing actions. Such activities either follow existing processes with well-established schedules and regulatory approaches or are being clarified through NRC initiatives outside of the ATF Steering Committee and Working Group.

In preparing 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 with the DOE to coordinate on ATF nuclear safety research that will provide the appropriate data for regulatory decisionmaking (ADAMS Accession No. ML17130A815). In addition, the NRC has established a memorandum of understanding with the Electric Power Research Institute (EPRI) to facilitate data sharing and coordination on expert elicitation (ADAMS Accession No. ML16223A497).

The same regulatory requirements apply to both near-term and longer-term concepts, and the NRC will evaluate each design using its individual technical basis. The timeline for licensing an ATF concept will be commensurate with its level of deviation from current practice and the number and complexity of the issues identified during an expert elicitation process (e.g., a phenomena identification and ranking table (PIRT) exercise). The agency is focusing its current licensing preparation on the use of ATF in light-water reactors (LWRs) in the operating fleet. Some overlap may occur between LWR ATF development and fuel safety qualification for some types of fuels for non-LWR and other advanced reactor designs. As appropriate, the NRC will leverage previous experience to optimize licensing efficiency and effectiveness and reduce schedule risk.

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[2] The industry uses the term "LEU+" to describe the enrichment levels to which the near-term ATF concepts will be enriched. Another term used by the industry and the DOE is "high-assay low-enriched uranium (HALEU)," which they define as fuel enriched to between 5 and 20 weight percent U-235. Both of these terms fall under the NRC regulatory definition of low-enriched uranium (LEU) in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.2, "Definitions," as fuel in which the weight percent of U-235 in the uranium is less than 20 percent.

This project plan is a living document and may evolve as (1) ATF concepts, higher burnup, and increased enrichment are more clearly defined, (2) schedules are refined, (3) the NRC staff's knowledge about 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 (see Figure 2-1), which consists of the executives who lead the technical and licensing divisions involved with ATF. The Director of the Division of Safety Systems in NRR heads the 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 Risk Assessment	• Division of Systems Analysis	• Division of Fuel Management • Division of Rulemaking, Environmental, and Financial Support

Figure 2-1 The NRC's ATF Steering Committee

The ATF Working Group consistently contains staff members from the divisions listed in Figure 2-2.

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

Figure 2-2 The NRC's ATF Working Group

Preparation for ATF, higher burnup, and increased enrichment is truly an agencywide effort that requires coordination and support from multiple technical, project, administrative, and legal organizations within the NRC.

3 ACCIDENT TOLERANT FUEL LICENSING PROCESS

This project plan focuses on the NRC's preparations for conducting efficient and effective reviews for ATF designs, higher burnup, and increased enrichment on a schedule consistent with industry-requested timelines.

The licensing of fuel design changes typically starts with submittal of a TR. TRs provide the generic safety basis for a fuel design and do not, by themselves, grant approval for operating plants to begin loading ATF-concept, higher burnup, or increased enrichment fuels. TRs for new fuel designs have historically taken 2 to 3 years to complete. Based on experience, vendors should also anticipate that the NRC's Advisory Committee on Reactor Safeguards (ACRS) may request to review TRs. Vendors should include time for such reviews in their planning and schedules. Typically, ACRS reviews can add 2-4 months, or longer, to the review schedule, depending on the circumstances. The NRC staff generally manages the schedule impact by proactively engaging ACRS staff early in the process to ensure that ACRS review is accomplished on a timeline that minimizes the overall impact to the schedule.

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. New fuel design LAR reviews are typically completed on an 18-month schedule; however, the length of time required to review an LAR for a new ATF design, higher burnup, or increased enrichment will depend on many factors. The NRC will provide an approximate LAR review timeline to the applicant only when it has received an application and performed an acceptance review to determine the scope of the review. Upon final approval of the plant-specific LAR, a licensee will 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, materials-related licensing actions are necessary for both the front end and the 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 increase allowed enrichment levels, fuel fabrication facility licensing for the manufacture of new fuel designs, changes to transportation package and dry cask certificates of compliance, and changes to specific licenses for independent spent fuel storage installations. This is discussed further in Section 7 of this plan. Many front-end licensing actions need to be completed before insertion of fuel with ATF designs, higher burnup, or increased enrichment into reactors. The use of ATF, higher burnup, and increased enrichment would not be possible without these vital materials-related licensing actions.

3.1 Assumptions

Because details on the development and deployment of ATF concepts are currently uncertain, the NRC staff has made the following major assumptions in 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 agency will receive all data needed to support the safety basis for a concept from the applicant, the DOE, NRC's involvement in international multiparty research projects, or NRC's interactions with other organizations. Additionally, the NRC expects to receive all reactor and test-generated fuel behavior data in a timely manner so that it can assess its analysis capabilities. If the NRC needs to perform confirmatory testing because of high safety significance and uncertainty, then the timelines detailed in this project plan no longer apply.

- The NRC's interactions with the DOE, EPRI, vendors, and other organizations involved in ATF-related experimental programs will take place in real time and, whenever possible, before experiments are conducted.

- The NRC's interactions with external stakeholders will keep the staff and stakeholders informed about both technical and programmatic developments that affect 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 will likely increase efficiency and effectiveness and reduce schedule risk in the NRC's review of ATF designs, higher burnup, and increased enrichment.

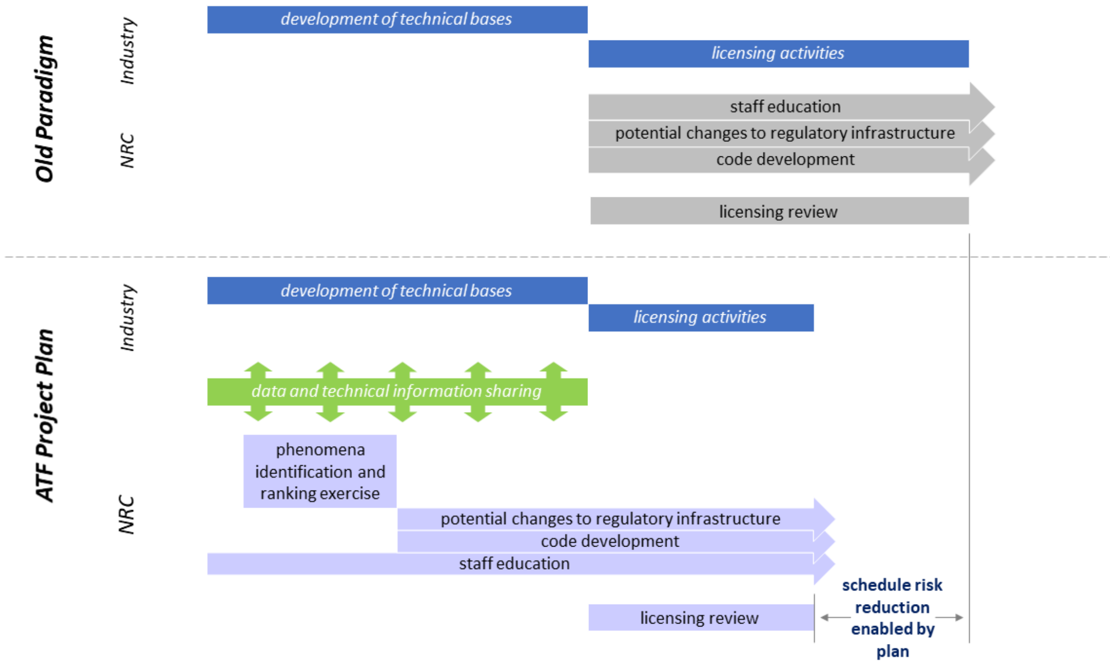

Figure 3-1 New Paradigm for the ATF Project Plan

3.2.1 Old Paradigm

In the old paradigm, the NRC played a reactive role in relation to the nuclear industry's activities. The NRC would often find out about a new technology only when a vendor or licensee submitted a licensing action or requested a presubmittal meeting close to the submittal date. At this time, NRC staff members would start three activities:

(1) educating themselves on the technologies through research and discussion with the applicant

(2) assessing potential changes to the regulatory infrastructure once they had enough information from the submittal or presubmittal meeting

(3) developing fuel analysis codes and models so that independent confirmatory calculations would be available for licensing needs

These activities would begin only after the development of the technical bases for the new technology. The lack of guidance and information exchange during this process could result in a mismatch between submittals and NRC staff expectations, possibly leading to resource-intensive requests for additional information (RAIs) and extending the time necessary to resolve technical or regulatory issues, resulting in significant schedule risk.

3.2.2 New Paradigm

The industry's pursuit of ATF, increased enrichment, and higher burnup has led the staff to reflect on the NRC's fuel licensing process, identifying possible improvements and ways to reduce schedule risk. The staff's new paradigm aims to enhance regulatory stability and reduce risk to the timeline 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 the industry to share data and information with the NRC staff in parallel to developing the technical basis for new technologies. Data sharing and early NRC staff engagement with vendors at this stage are critical in reducing schedule risk. In addition, the staff can begin learning about and gathering information on the technology much earlier than in the old paradigm. The NRC may conduct a PIRT exercise for each ATF concept, as explained in Section 3.2.3. Based on the outcome of the PIRT process or other preparatory activities, the staff may opt to make changes to the regulatory infrastructure. Any such changes will involve significant interaction with stakeholders to maintain transparency and clearly communicate regulatory expectations. The staff will also begin preparing agency analysis tools to minimize any lead time needed for performing confirmatory calculations after receiving applications.

The NRC staff has undertaken a review of its licensing processes (see Figure 3-2) to identify areas where additional efforts may contribute to ensuring an efficient and predictable licensing review. As a part of this review of licensing processes, the NRC staff developed the Licensing Pathway diagrams that were included in draft Version 1.2 of this plan, but have been removed in this final version. The NRC staff is continuing to refine the Pathways based on feedback received from stakeholders and will relocate them to the NRC's public web site once complete. Once there, the NRC staff will continue to refine them, as appropriate. In addition, the staff has taken steps to transform and streamline the topical report process. The changes made to the process are intended to provide a compressed schedule for submittals based on factors such as complexity and required level of staff effort. These streamlined processes have been in place for over a year. The success of the new paradigm depends on early industry engagement and voluntary sharing of information with the NRC. Without these two key activities, the licensing process will have to follow the old paradigm, resulting in greater schedule risk.

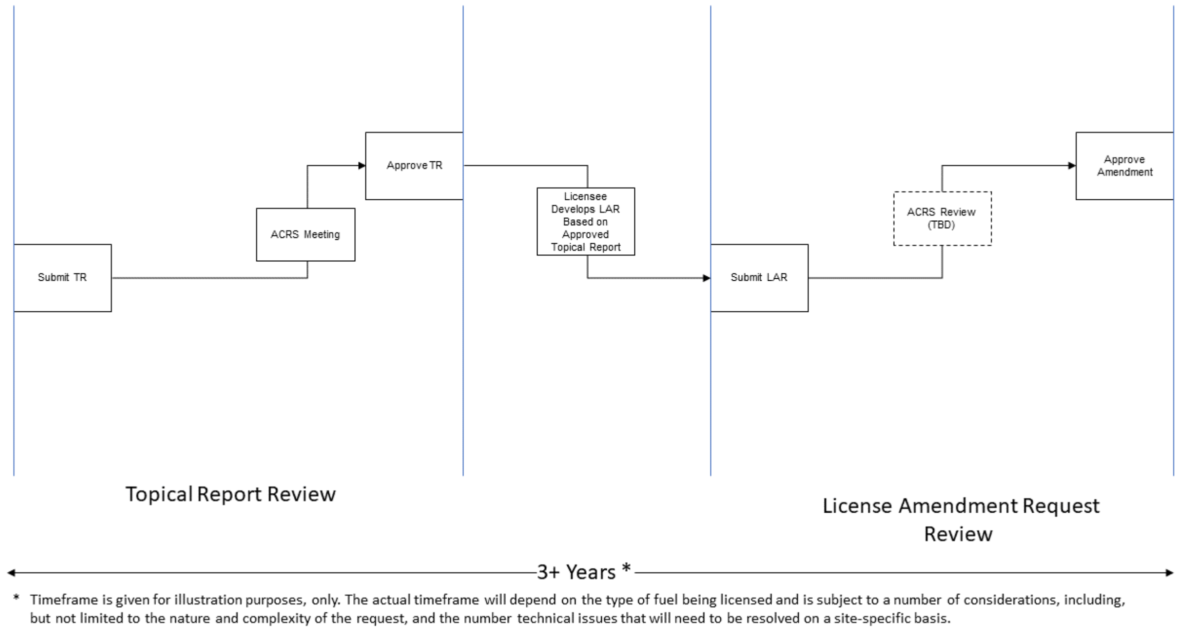

Figure 3-2 Generalized In-Reactor Licensing Process

3.2.3 Phenomena Identification and Ranking Table Exercises

As stated above, under the new paradigm, the staff could conduct thorough and meaningful PIRT exercises for each concept and update the PIRT results as the collective state of knowledge for design concepts is advanced. For the purposes of this project plan, the term "PIRT" is defined as an expert elicitation process in which panelists identify and rank new phenomena important to safety that are introduced by an ATF concept, higher burnup, or increased enrichment. The staff foresees that these exercises will vary greatly in scope and depth, depending on the maturity of each concept and the extent to which it departs from current practice.

During the review of current fuel licensing submittals, the NRC staff relies on the agency's considerable expertise in the Zr-clad UO_2 fuel system. However, the staff does not necessarily have that level of knowledge about all the ATF concepts or fuels with higher burnup, and increased enrichments that the 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 review of ATF, higher burnup, and increased enrichment licensing submittals. Through PIRT exercises, the NRC staff will benefit from external expertise in identifying phenomena important to safety for each concept. This will help the staff refine the necessary regulatory framework ahead of licensing submittals, preparing the 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 as or similar to those needed for 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, rather than as part of the concept-specific exercises.

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

The experts on the panel had backgrounds in high-temperature coatings and had worked in academia, national laboratories, and the nuclear industry. They discussed the initial report and their areas of expertise during a multiday public meeting. They finalized the report after rating a list of fuel damage mechanisms by importance and level of knowledge.

The final PIRT report was then used to develop interim staff guidance (ISG) on Cr-coated cladding, which will inform NRC staff reviews of Cr-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” (ADAMS Accession No. ML070660036).

While the NRC followed an expedited timeline in order to issue this ISG before the anticipated TR submittals on Cr-coated cladding, the staff has included stakeholders in the process. In particular, it opened the PIRT up as a public meeting, held multiple public meetings on the ISG, and issued a *Federal Register* notice soliciting public comment on the ISG (84 FR 57058). The NRC issued the ISG on January 3, 2020 (ADAMS Accession No. ML19343A121).

From September 2020 to April 2021, the NRC completed a second PIRT exercise on the performance in severe reactor accidents of the current ATF concepts, higher burnup fuels, and fuels with enrichment above 5 percent. It also assessed the impact of ATF, higher burnup, and increased enrichment on accident source terms. NRC contractors at Energy Research, Inc., led this PIRT exercise, which resulted in a final report in April 2021 (ADAMS Accession No. ML21113A277). This PIRT will inform source term calculations, performed with the MELCOR code. Results of these calculations will be used to determine if Regulatory Guide (RG) 1.183 will need updating to apply fully to higher burnup and ATF fuel.

The NRC will coordinate with external stakeholders to develop timelines for subsequent ATF PIRT exercises and additional implementation details.

3.2.4 Effectiveness of the New Paradigm

The new paradigm for fuel licensing is 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; completion of the actions in the new paradigm (and in this project plan as a whole) is not a go-or-no-go measure determining whether ATF technologies can be licensed. The current licensing and regulatory framework continues to apply to near-term ATF concepts, higher burnup, and increased enrichment. However, without the activities promoted by the new paradigm, there is increased schedule risk.

3.2.4.1 Effects of the New Paradigm on In-Reactor Topical Reports

Whether the NRC can complete the TR reviews on the industry's requested expedited timelines depends largely on 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 data into confirmatory codes. As shown in Figure 3-3, the more information and technical data the staff has received before and with a submittal, the better prepared the staff will be to perform an efficient review with less schedule risk. The amount of information and technical data necessary to minimize RAIs and conditions on use will vary depending on the topic. For example, coated cladding and doped pellets depart minimally from currently licensed fuel; therefore, the technical staff already possesses and understands much of the information and data necessary to make a safety determination. In contrast, information and data for higher burnup and increased enrichment are less available; therefore, more information will be needed to make a safety finding.

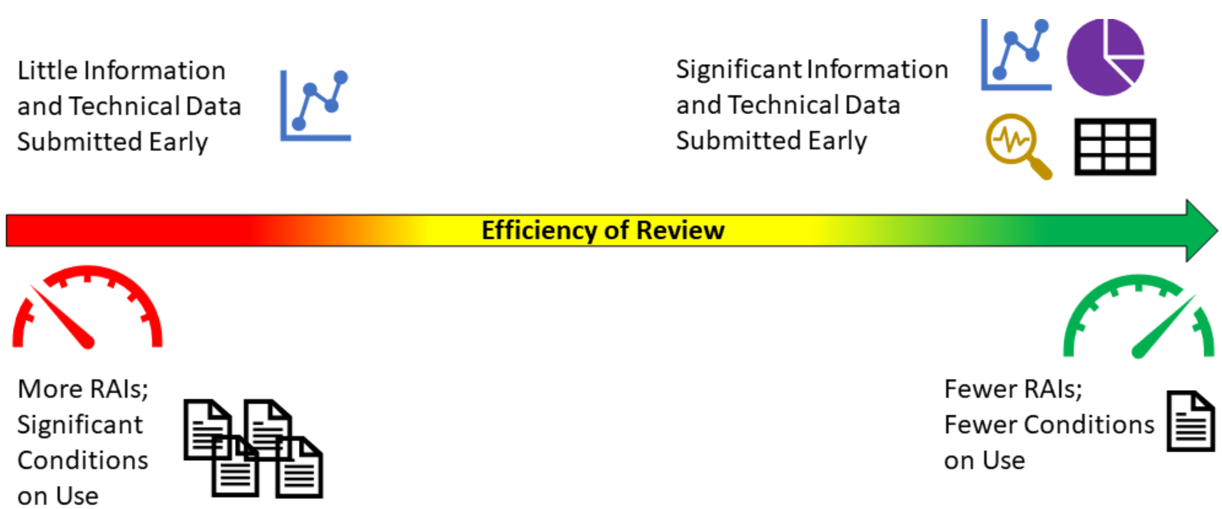

Figure 3-3 Data and Information vs. New Paradigm Efficiency

In addition, it is important for applicants to communicate with the NRC about their schedules, so that the NRC can adjust staff resources promptly for regulatory infrastructure changes (if any) and projected submittals. TR project managers will encourage vendors to discuss their TR plans early and often. Presubmittal meetings will be critical to ensuring efficient and effective reviews.

Finally, to meet the requested timelines, the NRC needs to receive high-quality[3] submittals. The increased communications and preapplication efforts will not succeed if applications are not complete and supported by data.

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

3.2.4.2 Effects of the New Paradigm on Licensing Actions

Many of the aspects of the new paradigm translate into efficiencies for front-end, in-reactor, and back-end licensing actions. Similar to the concept in Figure 3-3 for TRs, the more technical data and knowledge the staff has received before 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. Project managers in NRR and NMSS will encourage licensees and certificate holders to discuss their plans early and often, including in pre-submittal meetings.

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

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[3] A "high-quality" submittal contains, among other things, enough data and sufficiently detailed discussion to thoroughly support the assertions the applicant makes. Applications that do not adequately support their assertions often necessitate RAIs and extended review timelines, because the staff cannot make a safety determination without additional steps.

3.2.5 Lessons Learned within the New Paradigm

The following broad lessons learned from the NRC's experiences using the new paradigm with LTAs, TRs, and other licensing actions will improve the efficiency of reviews of ATF technologies:

- Information on the timing and types of submittals from power reactor licensees is important for resource planning.
- Early communication and preapplication interactions between the staff and applicants or licensees are essential for all licensing actions across the entire fuel cycle.
- The staff needs to know how the technology meets (or fails to meet) the consensus codes and standards or regulations before submittal.
- The staff needs to be familiar with past research and needs to be able to conduct appropriate confirmatory research to strengthen the basis for reasonable assurance of adequate protection of public health and safety.
- If data are still being collected, the applicant will need to compensate for the lack of data to provide a safety basis.
- Significant coordination across NRC offices is paramount.
- Significant coordination with DOE will continue to be important under the new paradigm.

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. This occurs through the issuance of documents, such as the Cr-coated cladding ISG mentioned earlier, and outreach activities, such as public meetings, conferences, and NRC-led workshops. The NRC is committed to actively engaging in industry project update meetings and to supporting staff participation in experimental program discussions to maintain awareness of industry and DOE preparations for regulatory reviews. The staff will continue to follow existing NRC policies for all stakeholder interactions, including with members of the public, related to ATF, higher burnup, and increased enrichment.

The NRC's enhanced stakeholder communications aim to do the following:

- Make the NRC staff more familiar with ATF concepts, which will enable more efficient review of ATF applications.
- Keep the NRC closely engaged with the organizations and entities acquiring data, so that it can adjust this project plan as new information becomes available.
- Reduce schedule risk by ensuring prompt recognition of required changes to regulations or guidance. The staff has initiated dialogue with stakeholders to communicate timelines required for modifying the regulatory infrastructure and to solicit input on changes that may be necessary for various ATF concepts.
- Allow more efficient NRC resource allocation given changes in the industry's direction and schedules.
- Provide opportunities for the public to interact with the NRC and provide input.

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 update meetings	Biannual	Assess technical progress of ATF research and development. Obtain information necessary for developing analytical capabilities and licensing strategies.

Meeting	Frequency	Desired Outcome
TOPFUEL fuels conference (rotates between the United States, Europe, and Asia)	Annual	Assess technical progress of ATF research and development. Obtain information necessary for developing analytical capabilities and licensing strategies.
ATF standards and guidance development activities with the Organisation for Economic Co-operation and Development, Nuclear Energy Agency, International Atomic Energy Agency, and international counterparts	Annual	Discuss licensing approach with international counterparts.
Fuel vendor update meetings (rotate between NRC Headquarters and vendor headquarters)	Annual (per vendor)	Assess technical progress of ATF research and development. Obtain information necessary for developing analytical capabilities and licensing strategies (as well as other non-ATF outcomes).
Industry ATF Working Group meetings	Quarterly	Discuss the status of ATF-related activities with representatives from industry and DOE.
Advanced Test Reactor (ATR)/Transient Reactor Test (TREAT) test planning and observation meetings	As scheduled	Develop an understanding of testing to measure the performance characteristics of ATF designs.
International conferences and workshops	As scheduled	Understand and coordinate ATF research and knowledge with international counterparts.
ATF fabrication facility tours and audits	As needed	Develop an understanding of manufacturing processes and obtain information for developing licensing strategies.
Participation on Collaborative Research on Advanced Fuel Technologies (CRAFT) and Extended Storage Collaboration Program (ESCP) committees	As scheduled	Assess industry progress 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. When possible, these meetings will contain a public portion for public comment.
NRC-initiated focused-topic meetings	As needed	Provide information and allow the public to interact with the NRC on specific technical and regulatory topics.

5 INITIATING STAFF ACTIVITIES

Because of design-specific factors and schedules, the NRC's activities are linked to the industry's progress with and plans to deploy ATF, higher burnup, and increased enrichment. For this reason, the industry must communicate schedules and resource needs in advance of licensing activities. One way to communicate schedules is through routine project manager interactions with vendors and licensees. Power reactor, vendor, and fuel cycle project managers will communicate with relevant vendors and licensees, as needed, to be aware of changes to schedules and changes in direction. Additionally, fuel vendors host routine update meetings, such as the annual fuel update meetings listed above. These meetings will also serve to inform the NRC of any changes to vendor schedules or direction.

When necessary, the staff will issue generic communications to obtain industry schedules. For example, by letter dated August 26, 2019 (ADAMS Accession No. ML19316B342), the staff issued, "Preparing for Efficient and Effective Licensing of Accident Tolerant Fuel with Higher Enrichment," to identify the key dates by which NRC should receive licensing and certification applications from fuel facilities and fuel vendors to support 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, TR submittals, and other licensing submittals from licensees under Title 10 of the *Code of Federal Regulations* (10 CFR) Parts 70, 71, and 72. The staff will issue generic communications to power reactor licensees as needed.

This project plan provides estimated lead times for all of the activities associated with the NRC's preparations to conduct effective and efficient licensing reviews of ATF TRs, LARs, and front-end and back-end licensing actions. Separate from this plan, the staff is continuing to develop Licensing Pathways that are intended to visualize the licensing process and information necessary to review applications for ATF-concept, higher burnup, and increased enrichment fuels. Once fully developed these Pathways will likely form the basis of a communication to industry similar to those described above. The staff's goal is to finalize the Licensing Pathways and make them available on the NRC's public website in calendar year 2021. As the staff gains experience with these reviews, it will adjust lead times to account for difficulties or efficiencies, as necessary. These lead times dictate when vendors or licensees should provide data ahead of submittals and when they should make a formal communication of intent through a response to an RIS, presubmittal meeting, or other formal interaction with the staff.

5.1 Initiating Activities for FeCrAl and Longer-Term ATF Technologies

The staff is aware that the industry's current focus is on coated cladding, doped pellets, higher burnup, and increased enrichment. If necessary, the NRC will begin refining the regulatory infrastructure for the other technologies (i.e., FeCrAl cladding, SiC cladding, UN pellets, and extruded metallic fuel) when the industry provides projected submittal dates for future licensing actions for those technologies. The staff will maintain communications with vendors and possible applicants to learn these submittal dates.

6 10 CFR PART 50, 10 CFR PART 52, AND 10 CFR PART 100 REGULATORY FRAMEWORK, IN-REACTOR PERFORMANCE

The regulations governing the design, siting, construction, and operation of power reactors are contained in 10 CFR Parts 50, 52, and 100. For a given fuel technology, the staff will use the result of the relevant PIRT to perform a review to: (1) evaluate the applicability of existing regulations and guidance (including consensus standards) for the given technology; (2) identify changes to, or the need for, new regulations and guidance; (3) identify any key policy issues; and (4) as needed, resolve policy issues and initiate rulemaking and guidance development activities.

The staff is also evaluating the changes to the in-reactor regulatory framework that may be required to support the implementation of higher fuel burnup and increased enrichment fuels within the industry-desired timeframes, given the consideration of the technical issues that 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 (FFRD) 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.

Based on the NRC staff's current understanding of the various approaches being considered, the staff has determined that the existing regulatory framework is sufficient to support the licensing of higher burnup and increased enrichment fuels. Therefore, any changes to the regulatory framework would be focused on enhancing certainty that the staff could complete its review within the requested timeframes. For example, the industry has expressed interest in using increased enrichment fuel above 5 weight-percent for LWRs by mid-2020s. In anticipation of these requests, the staff is investigating revising the regulations so that increased enrichment can be consistently licensed for use outside the exemption process.

The degree to which the NRC will need to revise existing regulations and guidance, or develop new regulations and guidance, will depend on how far the ATF concepts and burnup and enrichment levels pursued by the industry depart 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 the principal design and performance requirements. The general design criteria (GDC) listed in Table 6-1 relate to fuel design and overall fuel performance under normal and accident conditions. These and other GDC may be affected if the use of ATF introduces challenges 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 their applicability and identify any needs for additional criteria. For higher burnup and increased enrichment, the NRC staff has generally concluded that the GDC in Appendix A to 10 CFR Part 50 will not be directly affected. However, some criteria could be impacted indirectly. For instance, the figure-of-merit design dose criteria provided in GDC-19, Control Room, later codified as total effective dose equivalent (TEDE) in the 1999 rulemaking of 10 CFR 50.67, “Accident Source Term,” was developed during the late 1960s when burnup rates and enrichments were relatively low. There has been enough margin in the facilities’ design bases to accommodate the GDC-19 design criterion. Today, utilities are looking to extend peak-rod average burnup up to 80 GWd/MTU and enrichments of 8-10 weight-percent UO_2. Increases in burnup and enrichment for current fuel designs could challenge margins in facilities’ design bases, such as the 5 rem TEDE control room design criterion when performing traditional design basis accident analyses per the regulation. As such, the staff is considering a few options, as appropriate, including: (1) taking a risk informed approach to evaluating the control room design criteria in a manner that continues to ensure safety, or (2) exploring a potential rulemaking in which during the development of the regulatory basis, the staff would consider performing a more comprehensive review of the regulations associated with the life cycle of these fuels for operating light-water reactors. While higher burnup and increased enrichment may affect how licensees demonstrate compliance with regulatory requirements, the principal design and performance requirements of the GDC remain applicable.

Regarding higher burnup fuels, FFRD is a set of phenomena that have been observed where high burnup fuel pellets may, under certain reactor operating conditions, fracture, relocate within a fuel rod to a ballooned region, and if the fuel rod were to rupture, disperse into the primary coolant. The threshold for FFRD appears to be near the current burnup limit, and thus will need to be addressed in the licensing process for higher burnup fuel. The NRC has been part of international experimental programs to collect additional data on FFRD, and RES is preparing a research information letter (RIL) to NRR describing the current state of knowledge. The transmission of the final RIL will coincide with its public release, and is expected in March 2022.

Note that the loading of an ATF or increased-enrichment fuel design in a given plant will ultimately need to meet the 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 all operating plants).

Table 6-1 GDC Potentially Applicable to ATF

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
19	Control room
20	Protection system functions

GDC No.	Title
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

6.1 Additional Considerations

The staff understands industry may take an incremental approach in moving to higher burnup and increased enrichment. Therefore, the NRC staff envisions a phased approach for moving forward with the licensing of higher burnup fuels and fuels with increased enrichment. Initially, 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 to update existing regulations on enrichment levels to facilitate a more predictable licensing process.

Certain aspects of ATF, higher burnup, and increased enrichment designs or implementation strategies could expand the scope, level of complexity, and schedule of the staff's review of TRs and LARs. These include the following:

- consideration of environmental impacts;
- changes in accident source terms and operational source terms;
- lack of technical data for independent confirmatory calculations; and
- application of risk-informed approaches

When reviewing a request to adopt increased enrichment or higher burnup beyond the currently licensed limits, the staff will need to evaluate the potential environmental impacts of the request. Such evaluations could involve additional complexity, increasing 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 fuel and waste transportation. Thus, for each LAR review, the staff would need to produce a full description and detailed analysis of the environmental effects of transporting fuel and waste to and from the reactor with these higher enrichment and burnup levels.

To minimize this additional complexity for each LAR, the staff is considering whether to generically evaluate (i.e., perform a bounding evaluation) the environmental impacts of the transportation and waste associated with higher burnup fuels to and from reactors. To this end, the staff is assessing the available fuel performance analyses, data, and studies, as well as Addendum 1 to Volume 1 of NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" issued August 1999 (ADAMS Accession No. ML040690720); NUREG/CR-6703, "Environmental Effects of Extending Fuel Burnup above 60 GWd/MTU," issued January 2001 (ADAMS Accession No. ML010310298); and NUREG/CR-6672, "Reexamination of Spent Fuel Shipment Risk Estimates," issued March 2000 (ADAMS Accession No. ML003698324), along with assessing the available fuel performance analyses, data, and studies to determine if a generic study of ATF environmental impacts is feasible.

ATF 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 Zr-alloy cladding. These factors may affect accident source terms. Higher burnup and increased enrichment may also change accident source terms and operational source terms through changes in decay heat load and isotopic inventory. Accident source terms derived from updated data and studies of higher burnup and increased enrichments may be outside the limits of applicability outlined in current regulatory guidance and licensees will need to evaluate the impact of these source terms on their currently approved accident analyses of record and their environmental analyses. Additional challenges may exist if the revised source terms have environmental impacts that are not captured in or bounded by those discussed in NUREG-1437, Revision 1, issued June 2013 (ADAMS Accession No. ML13106A241). This could result in the need for an environmental assessment or environmental impact statement for an exemption request. In response to the PIRT on accident source term completed April 2021, the NRC staff is performing MELCOR calculations with assistance from Sandia National Laboratory for representative plants to determine whether existing source term guidance (e.g., RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," issued July 2000 (ADAMS Accession No. ML003716792) is applicable for near-term ATF concepts and for UO_2 fuel in Zr-alloy cladding over the increased ranges of burnup and enrichment being proposed. Incorporation of these results will follow the same process when developing the original NUREG-1465 "Accident Source Terms for Light-Water Nuclear Power Plants" (ADAMS Accession No. ML041040063) accident source term. While preliminary, it is expected that Sandia will complete and report their work to the NRC staff in early 2022. The NRC staff will then initiate an extensive peer-review process by setting up a panel of national and international experts with continued public and other stakeholder engagement. Following this process, the NRC staff will consider either all, or elements of, the Sandia report as an NRC NUREG for incorporation into the current ongoing revision of RG 1.183.

The independent confirmatory calculation capabilities highlighted in this project plan are used to expedite staff reviews. As discussed in Section 9, these capabilites depend heavily on material property data and experimental data to ensure that computer codes appropriately model key phenomena and accurately predict the parameters of safety importance. If these technical data are not received or are incomplete, the staff can account for uncertainties through the use of limitations and conditions for TRs and license conditions for LARs. Also, the staff can perform sensitivity analyses to determine which material or physical properties have the greatest effect on safety and tailor the limitations and conditions accordingly.

The staff is aware that the industry may pursue a risk-informed approach to licensing ATF concepts, higher burnup, and increased enrichment. The NRC's existing risk-informed framework can be used to support the licensing of nuclear fuel. For example, PIRTs use importance assigned by a panel of experts; the guidance for LTAs and their allowance within power reactors involves information that is inherently risk-informed; and the specified acceptable fuel design limits are generally performance based and are an intrinsic part of defense in depth, which is integral to the NRC's approach to considering risk in decisionmaking. The staff is engaging closely with industry to gain an understanding of their proposed approach and to communicate any information needs or issues raised related to the NRC staff's review of their approach. To that end, the staff is looking for additional opportunities to support pre-application activities, as appropriate. In addition, the staff is evaluating any potential policy issues that may arise from the pursuit of such an approach. Consistent with the new paradigm, the NRC encourages vendors and licensees considering a risk-informed approach to engage early with the staff to identify and resolve the relevant technical and policy issues.

6.2 Lead Test Assemblies

LTA programs provide poolside, 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.

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

6.3 Deliverables

No additional PIRTs or literature reviews are currently planned for in-reactor activities. However, if such literature reviews or PIRTs take place in the future, the staff will follow the schedule in Table 6-2.

Table 6-2 Anticipated In-Reactor Deliverables*

Title	Due Date (Near Term/Longer Term)
Map of hazards and failure mechanisms to GDC, regulations, and guidance documents	6–12 months from completion of the PIRT exercise or literature review
Development or revision of guidance to address any necessary changes identified	24–48/36–60 months from completion of the PIRT exercise or literature review
Rulemaking to address any necessary changes identified	24–48/36–60 months from identification of required changes

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

7 REGULATORY FRAMEWORK FOR FUEL FACILITIES, TRANSPORTATION, AND STORAGE

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

For a given fuel technology, the staff will 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. 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.

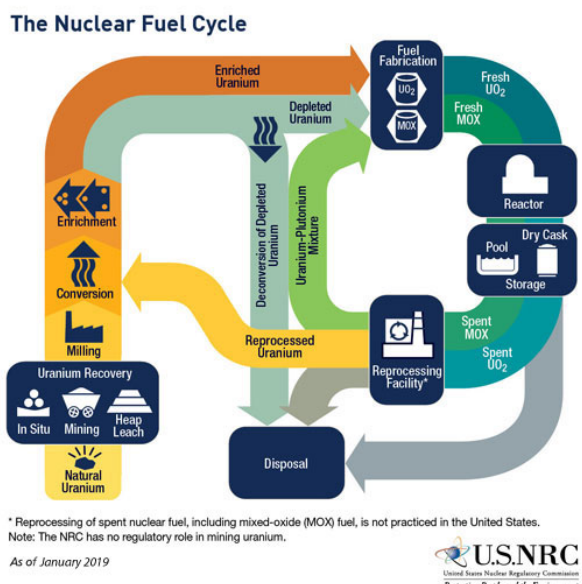

Figure 6-1 The Nuclear Fuel Cycle

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. Current guidance, review plans, and regulatory criteria, however, are adequate to address these issues. As noted below, some changes to regulations could be considered, to enhance the efficiency of reviews or reduce the number of limitations placed on licenses. 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, for successful deployment, any challenges must be addressed in the near term. To prepare for near-term licensing and certification reviews of ATF concepts with or without increased enrichment, the staff has been discussing licensing and certification strategies and approaches with applicants. The NRC has not identified any challenges to licensing or certification of ATF, however if one were to arise, the NRC will promptly communicate to stakeholders any potential technical or policy issues.

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 initiatives and licensing actions for reactor operation and will assess whether revisions to current guidance, review plans, and regulatory criteria are warranted for ATF concepts. The staff recognizes that licensing and certification actions related to the transportation and storage of ATF-concept spent fuel will not occur in the near term. The staff will engage with the industry as it develops plans on the back end of the fuel cycle and will update this project plan accordingly.

In relation to the safe transportation of material, the following technical issues are examples where consideration of modifications to the regulatory framework (10 CFR 71.55) may be considered to enhance the efficiency of the staff's reviews or reduce the number of limitations required for licensing:

(1) nuclear criticality safety for uranium hexafluoride (UF_6) transportation and fresh fuel assemblies,

(2) fuel assemblies (both fresh and irradiated) that rely on the fuel assemblies' structural performance to remain intact under accident conditions,

(3) the criticality evaluation of a single UF_6 package without using the exception in 10 CFR 71.55(g) (see Section 7.1.4.1 for a further discussion, and

(4) benchmarking criticality analyses for fuels with increased enrichment and burnup credit analyses for spent fuel storage and transport.

Each technical issue is likely to require different changes to the regulatory framework; however, the staff does not anticipate that it will need to make such changes before fuel with increased enrichment can be licensed or certified for general use in reactors. Section 7.1.4 of this project plan discusses these technical issues in detail.

The guidance documents that the NMSS staff rely upon to conducts its reviews draw on industry experience in the fabrication, transportation, and storage of Zr-clad UO_2 fuel with enrichment up to 5 weight percent and burnup up to approximately 62 GWd/MTU rod-average (or equivalent). Although the current guidance is sufficient to support licensing known near-term ATF concepts, higher burnup and increased enrichment fuels, the NRC may need to supplement its guidance in the future to address safety-related issues that could arise from ATF designs involving different fuel or cladding materials, higher burnup, increased enrichment, or changes in the processes and systems used to produce or manage the ATF. Areas for which review guidance may be expanded include criticality safety for systems with increased enrichment or higher burnup, fuel or cladding material properties that are used in the analysis of transportation or storage packages, and failure mechanisms for irradiated fuel other than Zr-clad UO_2. Two specific examples of which guidance may be developed are material properties for FeCrAl alloys and for SiC materials that are used as ATF cladding.

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

7.1 Fuel Facility, Transportation, and Storage Reviews

The regulatory reviews supporting the development and batch deployment of ATF designs with and without increased enrichment and higher burnup will occur in several fuel cycle areas, including 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 the reviews in each area.

7.1.1 Uranium Enrichment and Fuel Fabrication Facility Reviews

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

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

7.1.2 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 in Section 7.1.4.

The staff has reviewed four packages for transporting LTAs from fabrication facilities to reactors for test irradiation and still expects vendors that are developing ATF to request approvals for additional packages. 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 perform the safety reviews using the guidance in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material," issued August 2020 (ADAMS Accession No. ML20234A651). The staff has supported literature reviews and assessments of data needs that focus on criticality and shielding safety (code validation) and on material properties and performance of fuel cladding. (Section 10 includes a reference to the complete list of literature reviews.) These efforts should help the staff develop additional regulatory guidance, if required, for transportation of fuel with alternative cladding types and increased enrichment.

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.

7.1.3 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 or increased enrichment, the staff expects to receive requests for the approval of transportation packages under 10 CFR Part 71. For shipments of a limited number of irradiated LTAs within a limited timeframe, requests could be made under 10 CFR Part 71 (i.e., for letters of special authorization), similarly to requests for shipments of unirradiated LTAs. The staff will review these requests against the requirements of 10 CFR Part 71 and 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 with or without higher burnup or increased enrichment and are licensed under 10 CFR Part 72. The staff will review these requests against the requirements of 10 CFR Part 72 and will perform the safety review using NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities," issued April 2020 (ADAMS Accession No. ML20121A190). Future updates to 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 identifying and evaluating material properties and fuel degradation mechanisms to support the review of transportation packages or storage systems for irradiated ATF, with or without increased enrichment and higher burnup. These 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.

7.1.4 Potential Challenges

Certain aspects of ATF designs (with or without increased enrichment and higher burnup) and 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 for efficient licensing and the staff's current efforts to address those challenges.

The major near-term fuel cycle changes that could arise from ATF development are (1) increased enrichment (i.e., enrichment above 5 weight percent U-235), (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 effort required to review these fuel cycle changes depends on the number and nature of such changes. Table 7-1 identifies regulatory actions that these fuel cycle changes might require for fuel cycle facilities and operations.

Table 7-1 Potential ATF Fuel Cycle Actions 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 material with higher enrichment	License amendment to manufacture fuel with higher enrichment	Applications for new or amended transportation certificates for unirradiated, enriched feed material (e.g., UF_6 packages) and unirradiated and irradiated fuel assemblies	Applications for new or amended storage licenses or certificates of compliance 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 for higher burnup fuel
Different fuel material	Not applicable	NRC approval requests for facility changes that do not meet the criteria of 10 CFR 70.72(c)	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
Different fuel cladding	Not applicable	Not applicable	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 it is that supplemental review guidance will be required, and the more likely it is that the review will require greater staff effort. As an example, one potential ATF material, UN, is more susceptible to chemical reactions (e.g., with water or 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.

7.1.4.1 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 the most reactive moderation configuration for the transportation of UF_6 enriched to 5 weight percent or less. Transportation of UF_6 enriched to over 5 weight percent will require the design and certification of new packages or the modification of currently existing approved packages. Depending on the staff's safety findings, this may include an exemption from the regulations that require evaluation of a single package with the most reactive moderation for enrichments above 5 weight percent U-235. The NRC has engaged certificate holders and licensees on package approval requirements and potential evaluations for shipment of UF_6 with enrichments higher than 5 weight percent.

In addition to challenges identified above 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,"—which NRC certificates of compliance specify must be followed for UF6 package and which Department of Transportation (DOT) incorporates by reference in its regulations—limits enrichments to 5 weight percent uranium-235 for the 30B and 30C cylinders. For 12A/12B cylinders which can hold up to 460 pounds of UF_6, however, ANSI N14.1 limits for enrichments to 12.5 weight percent uranium-235. With regard to DOT regulations, 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 the American National Standard N14.1 that was in effect at the time the packaging was manufactured. DOT regulations in 49 CFR 173.420, which provide requirements for shipment of UF_6, limit the enrichment of 30B and 30C cylinders to 5 weight percent uranium-235 by incorporating N14.1 into its requirements. 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.

Benchmarking criticality analyses for fissile material enriched to over 5 weight percent U-235 presents a challenge because there are few critical experiments in that range. Applicants for package approval could potentially overcome this challenge by the following means:

- performing new critical experiments to validate criticality calculations for 5–10 weight percent U-235
- developing new critical experiments using sensitivity/uncertainty analysis methods
- using sensitivity/uncertainty analysis methods to determine that existing experiments are applicable to 5–10 weight percent U-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

- using some combination of the above options

In addition, applications to transport unirradiated ATF for batch loading could attempt to 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 Zr cladding is expected to have properties similar to those of conventional Zr cladding, confirmatory data on the mechanical properties and fatigue performance of ATF cladding will likely be needed to support the safety analyses for such credit. Similarly, applications to transport fuel that uses other cladding materials (e.g., FeCrAl or SiC) will need to include data to demonstrate adequate structural performance.

7.1.4.2 Challenges for Transportation and Storage of Spent Fuel

The criticality benchmarking concerns described above for unirradiated material also apply to transportation packages and storage casks containing spent fuel. 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, the staff will need to evaluate the accuracy of depletion calculations to derive the source term for the shielding analyses above 62 GWd/MTU rod-average (or equivalent).

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

- 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 aging-related degradation of ATF cladding and, if applicable, propose an aging management approach. NUREG-2214, “Managing Aging Processes in Storage (MAPS) Report,” issued July 2019 (ADAMS Accession No. ML19214A111), includes an evaluation of aging mechanisms for traditional Zr-clad fuel, but this evaluation does not necessarily apply to ATF. Therefore, renewal applicants may need to provide data demonstrating that age-related phenomena are not at play during extended dry storage of spent ATF.

7.2 Deliverables

At this time, one PIRT is planned for spent fuel transportation and storage activities, as shown in Table 7-2.

Table 7-2 Anticipated Fuel Cycle, Transportation and Storage Deliverables*

Title	Due Date (Near Term/Longer Term)
PIRT on cladding performance during spent fuel transportation and storage	Fiscal year 2023**
Development or revision of guidance to address any necessary changes identified	24–48/36–60 months from completion of the PIRT exercise or literature review

* The technical lead is the NMSS Division of Fuel Management.

** The PIRT schedule will depend on the availability of data on irradiated ATF.

8 PROBABILISTIC RISK ASSESSMENT ACTIVITIES

The NRC uses probabilistic risk assessments (PRAs) to estimate risk, identifying what could go wrong, how likely it is, and what the consequences could be. PRA results give insight 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 and the significance determination process portion of the Reactor Oversight Process). In these activities, the staff uses plant-specific PRA models developed both by licensees and by the NRC, the former mainly for licensing and operational activities and the latter mainly for oversight activities. A key tenet of risk-informed decisionmaking is that these models reflect the as-designed, as-operated plant. For this reason, the models should be updated to reflect significant plant modifications. The introduction of different fuel into the reactor core may affect these models, particularly if the reactor core composition strongly influences the plant's response to a postulated accident (e.g., by changing the time to fuel heatup and degradation or the amount of total hydrogen generation, or by producing higher decay heat from increased enrichment).

Activities needed to support risk-informed regulatory activities following the implementation of ATF, higher burnup, and increased enrichment could require significant NRC resources. To create a meaningful plan, the NRC needs information about the industry's intended approach. In early interactions within the PRA community on these topics, including preapplication meetings, the NRC has encouraged the industry to ensure that its approach is consistent with regulatory requirements and staff guidance. This project plan recognizes that the staff's preparatory work on PRA has two separate, but closely related, aspects:

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

(2) The staff needs to develop PRA-related capabilities to do the following effectively:

- Review risk-informed licensing applications and make sure that applicants are using acceptable PRA models once they have implemented ATF, higher burnup, or increased enrichment.

- Perform risk-informed oversight evaluations (e.g., the significance determination process) once licensees have implemented ATF, higher burnup, and/or increased enrichment.

Item 1 is highly dependent on the approach taken by each vendor or licensee in its licensing application. However, item 2 is somewhat independent of the licensing approach; therefore, this plan currently focuses more on item 2.

As the above categorization illustrates, PRA is broadly relevant to multiple aspects of ATF, not just to the incorporation of ATF safety enhancements into the licensing basis. Again, this is because the NRC’s risk-informed licensing and oversight approach relies on plant-specific PRAs that represent the as-built and as-operated plant. Near-term ATF designs may have limited impact on PRA modeling, whereas longer term ATF designs may have more impact. Incremental increases in fuel burnup and enrichment (such as enrichment increases on the order of tenths of a percent, or burnup increases in the low single digits of gigawatt-days per metric ton of burnup) may have little or no impact on PRA modeling. However, the larger increases that are anticipated, especially in combination with the other cladding and fuel changes associated with ATF adoption, may have a more significant impact.

The staff will need to ensure that licensees’ PRAs continue to use acceptable models and assumptions during the implementation of ATF. The staff will update the NRC’s models as necessary to reflect ATF-related plant modifications, higher burnup, and increased enrichment. In addition, staff will continue to 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). 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 batch loading into a particular plant. That said, plants using PRAs to support risk-informed operational programs (e.g., risk-informed technical specifications initiatives under 10 CFR 50.69, “Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors”) should update their models to realistically reflect the as-built, as-operated plant, in accordance with Regulatory Guide 1.200, “An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities (ADAMS Accession No.ML090410014). The NRC expects licensees to incorporate modifications affecting a plant’s risk profile (e.g., ATF, improved reactor coolant pump seals) into their PRA models under their existing PRA maintenance programs.

Much of the underlying deterministic knowledge needed to address these points can come from work covered elsewhere in this plan, particularly from the fuel performance, thermal hydraulics, and severe accident calculation capability development. The staff envisions that the analytical investigations needed to assess PRA-related effects and support PRA-related changes in the agency’s Standardized Plant Analysis Risk (SPAR) models can largely rely on the MELCOR modeling and analysis discussed in Section 9. If needed, the staff could also pursue additional confirmatory analysis 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,” issued September 2011 (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,” issued January 2016 (ADAMS Accession Nos. ML16021A423 and ML16022A062). This leveraging of resources for severe accident analysis tools and PRAs is routine.

In the near term, PRA-related effects can be assessed using the general knowledge being developed in these other ATF Project Plan areas, in conjunction with pilot efforts using the existing SPAR models. Such pilots would provide risk insights, identify 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.

At all stages, it is important for the NRC to engage on PRA-related topics both within the staff and with external stakeholders. Effective interaction will foster a common understanding of the acceptability of PRA methods to model plant modifications and of the ultimate impact of integrating these modifications into PRAs and risk-informed processes. It will also help ensure that information required to develop PRA modeling assumptions related to plant modifications is properly coordinated with the deterministic review. Since the NRC has identified the relevance of PRA early in the process, there is time to address PRA-related needs in a thoughtful manner that will support the staff's ultimate regulatory reviews.

To identify PRA-related milestones, the following assumptions are necessary (some restate assumptions made elsewhere in this plan):

- PRA-related efforts will be coordinated with the previously identified partner areas (e.g., severe accident analysis) so that the staff can leverage deterministic work to make the PRA-related efforts efficient. The NRC will reassess this approach as the industry's perspective evolves on the potential risk significance of ATF designs, higher burnup, and increased enrichment.

- This plan does not account for possible requests for new regulatory initiatives to maximize the operational or economic benefits of ATF, such as the following:

  - modifications to the categorization process in 10 CFR 50.69 associated with the use of relative (as opposed to absolute) CDF/LERF criteria

  - changes to requirements associated with security and emergency preparedness programs

  - rulemaking initiatives to facilitate rapid adoption of increased enrichment

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4 LERFs could change 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 encompasses the guidance used in risk-informed licensing and oversight (e.g., NUREG-0800; relevant RGs; Inspection Manual Chapter (IMC) 0609, "Significance Determination Process," dated November 9, 2020 (ADAMS Accession No. ML20267A146); and the Operational Events Handbook Volume 1 through 4 (ML17348A149, ML17349A301, ML102850267 and ML111370163). In reality, most of this guidance would not require revision because the concepts and processes would continue to apply. However, some aspects could require modification, such as those involving the LERF multipliers in IMC 0609, Appendix H, "Containment Integrity Significance Determination Process," dated March 23, 2020. Some guidance may also benefit from additional discussion of ATF impacts.

Tables 8-1 and 8-2 show the milestones and deliverables, respectively, for PRA activities.

Table 8-1 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 on 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 and a pressurized-water reactor 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 boiling-water reactor and a pressurized-water reactor 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 for ATF, higher burnup, or increased enrichment	Completion of the items above	1 year	Before the ATF core load[1]

	Milestone	Input Needed	Lead Time/ Duration	Needed By
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 generally be 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 8-2 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

9 DEVELOPING INDEPENDENT CONFIRMATORY CALCULATION CAPABILITIES

Independent confirmatory calculations are among the tools that the staff can use in its safety reviews of TRs, LARs, and front-end and back-end licensing actions. 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. Confirmatory calculations provide 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 to focus the staff's review. RG 1.70, Revision 3, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," issued November 1978 (ADAMS Accession No. ML011340122), indicates the format and content of licensee safety analyses, and NUREG-0800 identifies the criteria that the staff should use to review safety analyses.

The NRC plans to continue developing independent confirmatory analysis tools that support robust safety evaluations and provide insight into safety-significant factors for ATF designs, higher burnup fuels, and fuels with increased enrichment. Vendor codes used for modeling these technologies will likely be based on smaller datasets than those for the current Zr-UO_2 models. This implies greater uncertainty in the safety analysis results and the margins to the specified acceptable fuel design limits. Confirmatory calculations will therefore be critical for generating confidence in the safety assessments of ATF, higher burnup, and increased enrichment against all applicable regulatory requirements. Confirmatory codes can independently quantify the impact of modeling uncertainties and increase review efficiency by reducing the need for RAIs. Finally, the staff can leverage the experience and insights it gains from developing in-house codes to review externally developed models and methods, making its reviews more efficient and effective.

The staff has 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 has successfully used them to support regulatory decisionmaking. It is appropriate for the NRC to develop these codes further to strengthen its capability to analyze ATF designs, higher burnup, and increased enrichment. Tools for such analysis 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, applicants' computational tools will rely on properties and models for ATF, higher burnup, and increased enrichment that are based on limited experimental data.

The NRC will develop calculation capabilities through similar activities in each area, as follows:

- The staff will conduct PIRT exercises to ensure that it has identified and considered all new phenomena important to safety in the planning phases. PIRT results will inform code development.
- The staff will perform scoping studies or code evaluations to identify the architecture and model updates needed to model ATF concepts and designs.
- Where necessary, the staff will modify code architecture (e.g., to remove Zr-UO_2 hardwired properties and assumptions or to solve the governing equations for noncylindrical geometry).
- The staff will add material properties and develop new models where necessary.
- The staff will complete and document integral assessments of the updated codes. It is likely that the staff will use the results of integral assessments and uncertainty studies performed with updated codes to revisit and maintain PIRT products.

Figure 9-1 shows a generic schematic of tasks associated with developing calculation capabilities for near-term ATF concepts, higher burnup, and increased enrichment, whether such capabilities are developed by the applicant, the DOE, or the NRC.

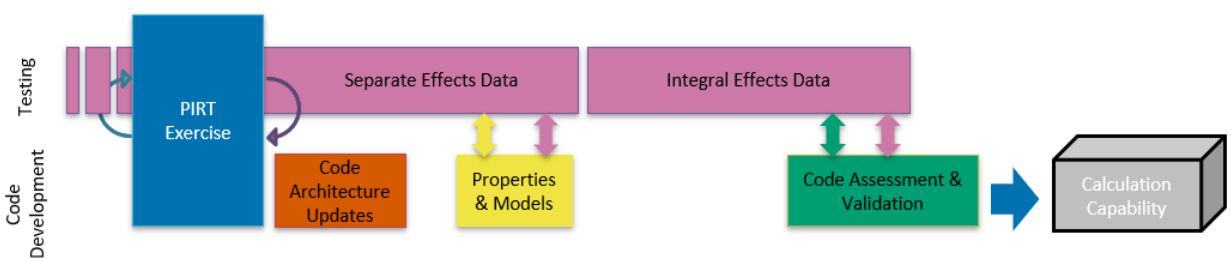

Figure 9-1 Development Process for Near-Term Calculation Capabilities

Figure 9-1 shows that code development requires testing and data to feed model development and validation. The process of developing codes to demonstrate safety includes updating codes with material properties and models for ATF, higher burnup, and increased enrichment, 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.

Much of the work to update codes for near-term ATF concepts has been completed. As described in Section 3.2.3, the NRC has sponsored two PIRTs to date, on the behavior of chromium-coated Zr-alloy cladding under in-reactor operating and accident conditions and on the behavior of ATF in severe reactor accident conditions (ADAMS Accession No. ML21113A277). The NRC has also sponsored literature reviews compiling relevant information for the performance of ATF in reactor, transportation, and storage conditions; the

NRC's public Web site gives more information on these. Finally, the NRC has updated its code architecture to make it more flexible and allow easier implementation of new material property models. This means that once experimental data become available, the NRC can quickly add new models to the code. Again, the NRC is relying on nuclear fuel vendors and the DOE 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, there is technical overlap between the disciplines, including the introduction of new material properties. To reduce duplication of effort, the analysis tools will be coupled to allow codes to exchange information. For example, neutronics codes can provide fuel performance codes with information on pellet radial power distribution as a function of burnup, and fuel performance codes can provide neutronics codes with fuel temperature and deformation calculations. Coupling codes in this way leverages information sharing to improve overall analysis capabilities and ensures consistency across codes.

In addition, the 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 NRC coordinates with DOE to reduce duplication of effort in calculation capability development. In particular, NRC staff meets regularly with representatives of DOE's Nuclear Energy Advanced Modeling and Simulation program to share recent code development and assessment activities for ATF.

10 COMPLETED PREPARATORY ACTIVITIES

The NRC staff has completed many activities in preparation for ATF, higher burnup, and increased enrichment submittals. Additionally, the NRC is already performing or has completed multiple reviews of these submittals. A complete list of these activities appears on the NRC's ATF public Web site, at https://www.nrc.gov/reactors/atf.html.

The Web site contains the following collections of ongoing and completed activities:

- The ATF-related licensing actions page lists all submitted ATF, higher burnup, and increased enrichment licensing actions and the completed NRC reviews, if applicable. This page can be found at https://www.nrc.gov/reactors/atf/licensing-actions.html.

- The ATF-related documents page lists all NRC-issued public documents relevant to ATF, higher burnup, or increased enrichment 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 lists all public meetings held since April 2018 on topics 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 on international cooperation and coordination, which is described on the ATF Web site international page, at https://www.nrc.gov/reactors/atf/international-interact.html.

11 PATH FORWARD

This project plan describes the NRC's high-level strategy to prepare for conducting efficient and effective reviews of ATF-concept, higher burnup, and increased enrichment fuels. The plan is a living document that may evolve as industry plans are refined and the state of knowledge for ATF concepts advances. Based on the strategy outlined in this plan, the staff intends to develop topic-specific assessments and action plans as necessary to provide additional information or to define the specific steps it will take to resolve issues. The staff will maintain these additional assessments and action plans separately from this project plan. For example, the staff is reviewing the applicability of existing regulations and guidance for the near-term ATF concepts, higher burnup, and increased enrichment and will develop concept-specific licensing roadmaps when necessary to clearly identify the regulatory criteria which must be satisfied for approval. The staff's goal is to finalize this and make it available on the NRC's public website in calendar year 2021.

APPENDIX A: CHANGE HISTORY

ITEM	LOCATION	REVISION	DESCRIPTION
1	Page 5, Section 2, Figure 2-1	1.1	ATF Steering Committee figure updated to reflect changes related to office mergers.
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	All	1.2	Editorial changes throughout.
9	Sections 6-10	1.2	Integrated the information in previous Section 6 with its corresponding location in Sections 7-10 and renumbered sections to reflect the deletion of Section 6.
9	Appendix A	1.2	Previous Appendix A incorporated into the main body of the project plan.
10	Appendix B	1.2	Appendix B removed because information was outdated and is available in other locations.
11	Appendix C	1.2	Appendix C on document change history changed to Appendix A.