APPENDIX A: FUEL BURNUP AND ENRICHMENT EXTENSION PREPARATION STRATEGY

Based on stakeholder interactions, the NRC staff is aware of industry's plans to request higher fuel burnup limits along with the deployment of near-term ATF concepts. Additionally, the staff expects that the extension of fuel burnup limits, and the economic drive to achieve those burnups, will result in requests to increase fuel enrichments to greater than the current standard of 5 weight percent U_{235}. Therefore, the staff is proactively assessing the current knowledge and experimental database associated with extending both burnup and enrichment for light water reactor (LWR) fuels. This plan focuses on the strategy to prepare the NRC for review of future licensing actions in which industry requests to go beyond current licensed limits with burnups up to ~75 GWd/MTU rod-average and enrichments up to ~8 weight percent U_{235}. Staff will continue to engage with industry and the fuel vendors on these topics and adjust this strategy as industry plans for higher burnup and increased enrichments evolve.

Overview of Preparatory Activities

As with other ATF activities related to advanced cladding and fuel materials, the staff has grouped its burnup and enrichment preparatory activities into four tasks. The highlights of each task are briefly described below; subsequent sections within this appendix describe these tasks in greater detail.

<u>Task 1: Regulatory Framework: In-Reactor Performance</u>

- Participate in coordinated PIRT exercises on in-reactor performance of fuels with increased enrichment under a wide array of conditions, performance -based metrics, and analytical criteria to ensure acceptable performance.
- Perform a scoping study to (1) evaluate the applicability of existing regulations and guidance for higher burnups and increased enrichment, (2) identify changes to, or the need for, new regulations and guidance, and (3) identify any key policy issues.
- Identify consensus standards that need to be updated for higher burnups and increased enrichment and participate in the update process where appropriate.
- Determine and clarify the regulatory criteria that need to be satisfied for higher burnup fuels and fuels with increased enrichment and the regulatory options available to applicants and vendors.
- If needed, resolve policy issues and initiate rulemaking and guidance development activities.

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

- 10 CFR Part 70, “Domestic Licensing of Special Nuclear Materials” is performance based; therefore, the staff does not anticipate identification of gaps or deficiencies in these regulations for the licensing of enrichment facilities to produce increased enrichment material or fuel fabrication facilities to fabricate increased enrichment fuel. The staff has previously licensed plants that produce uranium fuel enriched to the levels addressed in this plan.
- 10 CFR Part 71, “Packaging and Transportation of Radioactive Material”; and 10 CFR Part 72, “Licensing Requirements for the independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,” are largely performance based; therefore, the staff does not anticipate identification of gaps or deficiencies in these regulations.
- Gaps in the review guidance may develop as the fuel cycle industry develops plans for manufacturing, transporting, and storing higher burnup and increased enrichment fuel. The NRC will monitor the fuel cycle industry’s plans and identify and develop any necessary regulatory guidance in a timely manner.
- The NRC is engaging industry to understand the details and timing of its plans to produce uranium hexafluoride (UF_6) that is enriched above the current limit (5 weight percent U_{235}) and fabricate increased enrichment LWR fuel.

Task 3: Probabilistic Risk-Assessment Activities

Like the impacts of ATF cladding and fuel matrix concepts, higher burnups and increased enrichments manifest in a probabilistic risk assessment (PRA) via impacts on the plant’s response to a postulated accident, in the form of changes to assumptions about sequence timing, success criteria, and severe accident phenomenology. The PRA activities described in the main body of this document (i.e., the activities originally crafted to address changes in plant response to beyond-design-basis accidents associated with ATF) may adequately encompass the PRA-related work needed to address the impacts of higher burnups and increased enrichments. The specific timeframes and nature of the industry activities and associated NRC deterministic technical basis development will dictate this. For instance, the pilot PRA model work described in Section 9 may be able to accommodate the potential burnup and enrichment changes combined with the other cladding and fuel response impacts associated with ATF. The degree of coverage provided by the pre-existing planning will also depend on the degree to which burnup and enrichment changes impact other agency uses of PRA information (such as in assessing environmental impacts associated with postulated accidents). At this time, the staff is assessing whether higher burnup and increased enrichments warrant any additional or different ATF-related PRA work, and the staff will adjust its planning accordingly.

Task 4: Developing Independent Confirmatory Calculation Capabilities

Independent confirmatory calculations are one of the tools that the staff can use in its safety review of topical reports and license amendment requests. Confirmatory calculations provide the staff insight on the phenomenology and potential consequences of transient and accident scenarios. In addition, sensitivity studies help to identify risk significant contributors to the safety analyses and assist in focusing the staff's review.

The staff's approach to modifying and validating existing NRC codes and performing confirmatory analysis for burnup and enrichment extension will be similar to the approach for ATF described in Section 6.4 in the ATF Project Plan. At this time, the NRC plans to modify its codes that are developed to analyze fuel performance, thermal hydraulics, neutronics, and severe accidents and source terms to support confirmatory analysis of fuels with higher burnup and increased enrichment. See Section 6.4 and Appendix B of the ATF Project Plan for further details.

A.1 Task 1: Regulatory Framework: In-Reactor Performance

Higher fuel burnups and increased enrichments present new and unique technical issues that current guidance, review plans, and regulatory criteria may not readily address. To prepare the agency to conduct meaningful and timely licensing reviews of higher fuel burnup and/or increased enrichment proposals, well-developed and vetted positions are needed on potential policy issues that may arise during the review and licensing process. These positions must be communicated to stakeholders clearly and early.

This task addresses the changes to the in-reactor regulatory framework that may be required to support the implementation of higher fuel burnups and increased enrichments considering the technical issues they present. Generally, the technical issues associated with higher fuel burnups and increased enrichments respectively fall into two categories, fuel integrity (cladding and/or fuel pellet) and nuclear criticality safety. ECCS performance embrittlement mechanisms and fuel fragmentation, relocation, and dispersal (FFRD) are examples of fuel integrity technical issues. Spent fuel pool criticality, and potential fast critical conditions during accident scenarios are examples of the technical issues that fall under nuclear criticality safety. The regulatory framework changes that may be necessary to address each technical issue are likely to be different, and the staff anticipates that such changes will need to be made before either higher fuel burnups or increased enrichments can be licensed for general use.

With regard to the regulations at Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” the NRC staff has concluded that the general design criteria (GDC) discussed therein will not be affected by higher burnups and increased enrichments. While higher burnups and increased enrichments may impact the way compliance with regulatory requirements The degree to which existing regulations and guidance need revision or new regulatory requirements and guidance need to be established, depends on the level of departure from existing burnup and enrichment limits. is demonstrated, the actual principal design and performance requirements provided by the GDC remain applicable. Note that loading increased enrichment fuel designs in a specific plant will ultimately need to meet relevant plant-specific criteria. This is especially important for those reactors in the United States that were licensed before the issuance of the GDC (about 40 percent of the operating plants).

Beyond the GDC, higher burnups and the use of fuel with increased enrichment may affect the regulations and guidance related to fuel design and performance and nuclear criticality safety listed in Tables A.1 and A.2, below. The staff plans to map the technical issues and potential failure issues to these requirements and guidance to determine the scope of changes that are necessary.

Table A.1 Potentially Affected Regulations

Regulation (10 CFR)	Title	Affected by:	
		Burnup	Enrichment
20	Standards for Protection Against Radiation		✓
50.34	Contents of Applications; Technical Information	✓	✓
50.46	Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors	✓	✓
50.67	Accident Source Term	✓	✓
50.68	Criticality Accident Requirements		✓
50, Appendix K	ECCS Evaluation Models	✓	✓
51	Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions (specifically, Tables S-3 and S-4)	✓	✓
100	Reactor Site Criteria	✓	✓

Table A.2 Potentially Affected Guidance

Guidance Document	Title	Affected by:	
		Burnup	**Enrichment**
NUREG-0630	Cladding Swelling and Rupture Models for LOCA Analysis	✓	
NUREG-0800	Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (Section 4.2, “Fuel System Design” in particular for burnup)	✓	✓
NUREG-1465	Accident Source Terms for Light-Water Nuclear Power Plants	✓	✓
NUREG-1555	Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan		✓
NUREG-2121	Fuel Fragmentation, Relocation, and Dispersal During the Loss-of-Coolant Accident	✓	
NUREG/CR-7022 Vol. 1-2	FRAPCON-3.5	✓	✓
NUREG/CR-7023 Vol. 1-2	FRAPTRAN 1.5	✓	✓
NUREG/CR-7024	Material Property Correlations: Comparisons Between FRAPCON-3.5, FRAPTRAN 1.5, and MATPRO	✓	✓
NUREG/CR-7219	Cladding Behavior During Postulated Loss-of-Coolant Accidents	✓	
RG 1.183	Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors	✓	✓
RG 1.195	Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors	✓	✓
RG 1.203	Transient and Accident Analysis Methods	✓	✓
DG 1327	Pressurized Water Reactor Control Rod Ejection and Boiling Water Reactor Control Rod Drop Accidents	✓	✓

A.1.1 Additional Considerations

Aspects of higher burnup and increased enrichment fuel designs or the implementation strategy could expand the scope, level of complexity, and schedule of the staff’s review. Specifically, an increase in fuel burnup and U_{235} enrichment could impact the scope of the staff’s environmental review and have implications for the license renewal generic environmental impact statement (GEIS) associated with a plant’s licensing basis.

Higher fuel burnups and increased enrichments may affect the NRC's generic environmental findings as documented in the GEIS. Licensees seeking to adopt higher fuel burnups and increased enrichments beyond the current licensed limits will need to submit a license amendment request, and this submittal will need to provide sufficient information as to the potential environmental impacts of the request to facilitate the staff's review. Such information should consider justification for the continued applicability of the existing generic basis as presented in the GEIS. The NRC staff will need to undertake a review of the justification, and this could be a source of additional complexity. To minimize this additional complexity, the staff may need to reassess the current basis for Table S-3 and Table S-4 of 10 CFR Part 51 as documented in the GEIS, how it may be impacted by higher burnup fuels and increased enrichment, and the changes that may be necessary to generate an updated technical basis and GEIS. The necessity of this effort will become clearer as NRC continues engagement with industry and the fuel vendors.

A.1.2 Lead Test Assemblies

Lead Test Assembly (LTA) programs provide pool-side post-irradiation examination data collection, irradiated material for subsequent hot-cell examination and research, and demonstration of in-reactor performance. This characterization of irradiated material properties and performance is essential for qualifying analytical codes and methods and developing the safety design bases for higher burnup fuels and fuels with increased enrichments.

The NRC has recently published a letter to the Nuclear Energy Institute (ADAMS Accession No. ML18100A045) that documents the agency's position concerning criteria for the insertion of LTAs under 10 CFR 50.59 without additional NRC review and approval. LTA programs for higher burnup and increased enrichment may fall outside the guidance in the letter and require LARs, depending on the scope of the LTA campaign and the licensing basis of the reactor.

A.1.3 Licensing Strategy

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

A.1.4 Deliverables

Table A.3 Anticipated In-Reactor Deliverables*

Title	Due Date
Map of technical issues and failure mechanisms to regulations, and guidance documents.	6–9 months from completion of the PIRT exercise
Develop or revise guidance to address any identified necessary changes.	18–24 months from completion of the PIRT exercise
Develop rulemaking to address any identified necessary changes.	24–36 months from identification of required change

* The technical lead is the NRR Division of Safety Systems, Nuclear Performance and Code Review Branch

A.2 Task 2: Regulatory Framework: Fuel Cycle, Transportation, and Storage

The regulatory activities on ATF of higher burnup/increased enrichment present different challenges at the various stages of the front and back end of the fuel cycle. The NRC recognizes that these challenges have different timelines, with increased enrichment being the near-term technical issue that must be addressed for successful deployment of ATF.

For the front end of the fuel cycle, which includes fuel assembly fabrication and transportation of feed material and fresh fuel assemblies, increased enrichment may present additional technical and regulatory issues; however current guidance, review plans, and regulatory criteria are adequate to address these issues. To prepare the agency to conduct near-term timely licensing and certification reviews of increased enrichment levels for ATF, discussion of licensing/certification strategies and approaches between applicants and NRC will be undertaken to address any potential technical or policy issues that may arise. Any issues the NRC identifies will be communicated to stakeholders promptly.

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

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

A.2.1 Regulatory Infrastructure Analysis

The regulatory requirements in 10 CFR Part 70, 10 CFR Part 71 and 10 CFR Part 72 govern the use of radioactive material for fuel enrichment and fabrication facilities, transportation, and spent fuel storage. 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. The criticality regulations in 10 CFR 71.55(g) grant an exception from the consideration of moderation intrusion for the transportation of UF_6 enriched to 5 weight percent or less. Transportation of UF_6 enriched to greater than 5 weight percent will require the design and certification of new packages, the modification of currently approved packages, or an exemption from the regulations that require evaluation of a single package with optimum moderation for enrichments greater than 5 weight percent.

Table A.4 identifies the current guidance documents for the review of fuel facility licensing, transportation package certification, and spent fuel storage licensing and certification and identifies whether the guidance document is affected by industry plans to use higher enriched, higher burnup fuel.

Table A.4 NRC Fuel Cycle Review Guidance

Review Guidance Document	Title	Affected By	
		Burnup	**Enrichment**
NUREG-1609[1]	Standard Review Plan for Transportation Packages for Radioactive Material	✓	✓
NUREG-1617[1]	Standard Review Plan for Transportation Packages for Spent Nuclear Fuel	✓	✓
NUREG-1520	Standard Review Plan for Fuel Cycle Facilities License Applications		
NUREG-2214	Managing Aging Processes In Storage (MAPS) Report	✓	
NUREG-2215	Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities	✓	✓
NUREG-2224	Dry Storage and Transportation of High Burnup Spent Nuclear Fuel	✓	
Spent Fuel Storage and Transportation Interim staff guidance[2]	https://www.nrc.gov/reading-rm/doc-collections/isg/spent-fuel.html[3]	✓	✓

[1] Note that NUREG-1607 and NUREG-1617 are being combined into a single standard review plan, NUREG-2216, "Standard Review Plan for Transportation Package Approval," which is scheduled to be completed in the summer of 2020.

[2] After completion of NUREG-2215 and NUREG-2216, all existing Interim Staff Guidance documents issued by the Division of Spent Fuel Management will be retired.

[3] In particular, SFST-ISG-8, Revision 3, "Burnup Credit in the Criticality Safety Analysis of PWR Spent Fuel in Transport and Storage Casks," is affected by both higher burnup and increased enrichment.

These review guidance documents draw on industry experience in the fabrication, transportation, and storage of Zrclad- UO_2 fuel with up to 5 weight percent enrichment and burnup up to approximately 62 GWd/MTU rod average. The NRC may need to supplement its guidance to address safety related- issues associated with increased enrichments and higher burnups. When staff believes that supplemental information or guidance would facilitate the preparation and review of applications involving the enrichment, fabrication, transportation, and storage of higher burnup and/or increased enrichment fuel, it will discuss this with stakeholders and take action where practical.

A.2.2 Facility, Transportation, and Storage Reviews

The regulatory reviews to support the development and deployment of increased enrichment fuel will occur in several fuel cycle areas over the near term to support production (enrichment and fuel fabrication) and transportation of UF6 feed material and fresh fuel assemblies. The sections below discuss these various reviews.

A.2.2.1 Uranium Enrichment and Fuel Fabrication Facility Reviews

The uranium enrichment facilities that produce enriched uranium as well as fabrication operations that would produce conventional fuel (e.g., Zr-clad UO2) with increased enrichment will conduct operations that are similar to currently licensed operations. These licensees will have to submit amendments to produce or use uranium with increased enrichment. Fuel fabrication operations that use new processes for producing a different type of fuel material (e.g., uranium alloy or U_3Si_2) are expected to submit amendments to address both increased enrichment as well as the new processes.

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

A.2.2.2 Unirradiated Fuel Transportation Package and Storage Cask Reviews

As industry prepares for the batch loading of higher burnup and increased enrichment fuel, 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 fuel assemblies. The staff will review these requests against the requirements of 10 CFR Part 71 and will use NUREG-1609 and pertinent interim staff guidance for the safety reviews. The NRC staff will support PIRT efforts that focus on the identification and evaluation of material properties used in the safety analyses of transportation packages with higher burnup and increased enrichment. These PIRT efforts are expected to help the staff develop additional regulatory guidance for transportation of fuel with increased enrichment, if required.

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

A.2.2.3 Irradiated Fuel Transportation Package and Spent Fuel Storage Reviews

The back end of the fuel cycle—spent fuel storage and transport—presents some challenges that are similar to the front end. For example, benchmarking criticality safety is still an issue for the back end for enrichments between 5 and 8 weight percent, but additional challenges may exist depending on the licensing/certification strategy. Other areas where challenges may exist include, performance of the cladding material during vacuum drying, aging while in dry cask storage, fatigue data for transportation, and benchmarking the isotopic depletion analyses for use in the shielding analyses for higher burnup fuels and for use in burnup credit criticality analyses.

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.

A.2.2.4 Potential Challenges

NRC staff has identified technical challenges for transportation of unirradiated fuel and spent fuel with higher burnup and increased enrichment.

A.2.2.4.1 Challenges for Transportation of Unirradiated Fuel

In addition to challenges for approval of transport of UF_6 at increased enrichments (greater than 5 weight percent), it should be noted that American National Standards Institute (ANSI) N14.1, “Nuclear Materials — Uranium Hexafluoride – Packagings For Transport,” only applies to enrichments up to 5 weight percent ^{235}U for the 30B and 30C cylinders. DOT regulations in 49 CFR 173.420 state that UF_6 packagings (whether fissile, fissile excepted, or non-fissile) must be designed, fabricated, inspected, tested and marked in accordance with American National Standard N14.1 that was in effect at the time the packaging was manufactured. 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 greater than 5 weight percent ^{235}U presents a challenge due to the limited number of critical experiments in that range. Applicants for package approval could overcome this challenge by performing:

- new critical experiments to validate criticality calculations for 5-8 wt% enriched uranium,
- relying on sensitivity/uncertainty analysis methods to develop new critical experiments,
- relying on sensitivity/uncertainty analysis methods to determine that existing experiments are applicable to 5-8 wt% enriched uranium, or
- reduce the allowable maximum k-effective to account for uncertainties in criticality code performance due to lack of applicable critical experiments for benchmarking.

A.2.2.4.2 Challenges for Transportation and Storage of Spent Fuel

In addition to the benchmarking challenge listed above, other challenges exist for the storage and transportation of spent fuel. Evaluation of material performance during vacuum drying, aging while in storage, and cladding material properties are needed to evaluate structural performance during normal storage, transport, and accident conditions.

Aging effects during long-term, dry cask storage include evaluation of impacts of potential operable age-related phenomena on cladding performance. Those mechanisms described in NUREG-2214 that may be affected by higher burnup and increased enrichment include creep, hydrogen absorption, oxidation, delayed hydride cracking, and irradiation hardening. In addition, the impacts of both potential higher end-of-life rod internal pressures on the credibility of age-related phenomena, and the increased pellet swelling on the mechanical performance of the cladding should be evaluated. There is also a need for experimental confirmation to determine whether unknown age-related phenomena impact the spent fuel during storage and transport after storage.

In addition to cladding material properties discussed above for unirradiated fuel, fatigue performance data will be needed to evaluate vibration normally incident to transport as required in 10 CFR 71.71(c)(5).

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

However, these challenges would not preclude an effective and efficient staff review.

A.2.2.5 Anticipated Regulatory Actions

Near -term regulatory actions consist of the reviews of fuel cycle facilities license amendments. There are other regulatory actions needed to support increased enrichment and higher burnup; however, only one fuel cycle facility have shared plans to submit a license amendment. Other expected regulatory actions will be identified in future revisions of the plan after industry plans become clearer.

A.3 Task 3: Probabilistic Risk Assessment Activities

The NRC uses PRAs to estimate risk: to investigate what can go wrong, how likely it is, and what the consequences could be. The results of PRAs provide the NRC with insights into the strengths and weaknesses of the design and operation of a nuclear power plant. PRAs cover a wide range of NRC regulatory activities, including many risk-informed licensing and oversight activities (e.g., risk-informed technical specification initiatives, the significance determination process portion of the Reactor Oversight Process). These activities make use of both plant-specific licensee PRA models and plant-specific NRC PRA models. The NRC uses the former models predominantly for licensing and operational activities and the latter models predominantly for oversight activities. A key tenet of risk-informed decision-making is that these models reflect the as-designed, as-operated plant. For this reason, these models should be updated to reflect significant plant modifications. The introduction into the reactor core of fuels intended for higher burnups and fuels with increased enrichments may affect these models, particularly once the reactor core composition significantly influences the plant's response to a postulated accident (e.g., higher initial decay heat from increased unrainum-235 enrichment).

Developing capabilities to support risk-informed regulatory activities following the implementation of higher fuel burnups and increased enrichments could require significant NRC resource. Information about the industry's intended approach is needed to create a meaningful plan. Early NRC interactions with the industry and vendors regarding higher burnup and increased enrichment activities, such as fuel technology update meetings and early preapplication meetings, will be used to encourage an approach that is consistent with regulatory requirements and staff guidance. Just as with the ATF project plan, this project plan recognizes that the staff's PRA-related preparatory work involves 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 the batch loading of fuels with increased enrichments and higher burnups as well as the incorporation of these technologies into the licensing basis.

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

- Review risk-informed licensing applications and ensure that applicants are using acceptable PRA models once higher fuel burnups and increased enrichments are implemented.
- Perform risk-informed oversight evaluations (e.g., significance determination process) once higher fuel burnups and increased enrichments are implemented.

Item 1 is highly dependent on the approach taken by each vendor or licensee, or both, in its licensing application, while item 2 is somewhat independent of the licensing approach. Therefore, this project plan currently focuses more attention on item 2.

In the near-term, increases in fuel burnup and enrichment limits are expected to be only marginally greater than current limits, and this may have only a limited or no impact on PRA modeling. However, in the long term, increases in fuel burnup and enrichment limits are expected to be appreciably greater than current limits, and this may have a more significant impact on PRA modeling.

PRA activities for higher burnups and increased enrichments will be analogous to the activities for ATF described in Section 9 of this document. In particular, NRC staff must ensure that licensees' PRAs continue to use acceptable models and assumptions as part of the implementation of higher burnup fuels and fuels with increased enrichments and update the NRC's models (as necessary) to reflect any plant modifications made to accommodate these new technologies. Also analogous to the activities for ATF, it is envisioned that much of the analytical investigation needed to assess PRA-related impacts and support PRA-related changes in the agency's SPAR models due to higher burnups and increased enrichments can use the independent confirmatory calculational capabilities currently being developed by the NRC. These capabilities are discussed in Section A.5 of this project plan. See Section 9 of this document for further information on the analogous PRA activities NRC will take in response to higher burnups and increased enrichments.

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

For the purpose of identifying PRA-related milestones, the following key assumptions are necessary:

- The timing of PRA-related efforts will be cross-coordinated with those of the previously identified partner areas (e.g., severe accident analysis) to allow the leveraging of deterministic work to make the PRA-related efforts efficient.
- Near-term TR/LAR reviews will start in 2020, with long-term licensing reviews occurring no earlier than 2023.
- This plan does not account for rulemaking initiatives that might be requested to facilitate rapid adoption of increased enrichments (e.g., modifications to 10 CFR 50.68, "Criticality Accident Requirements").

The PRA-related milestones for higher burnups and increased enrichment activities are listed below in Table A.6. It should be noted that it may be feasible to merge the work outlined in Table A.6 with the existing ATF PRA-related milestones found in Table 9.1, depending on the nature and timing of the higher burnup and increased enrichment activities relative to that of the ATF activities.

Table A.6 PRA Activities for Higher Burnups and Increased Enrichments—Milestones

	Milestone	Input Needed	Lead Time/ Duration	Needed By
1	Participate in internal and external discussions and knowledge development related to higher burnups and increased enrichments (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 licensing higher burnup fuels and increased enrichments	More information regarding the specific licensing approach	TBD	TBD
3	Complete a SPAR pilot of a BWR and PWR subject plant for higher burnups and increased enrichments to assess CDF/LERF impacts, gain risk insights, and identify potential improvements to guidance	Deterministic knowledge base being developed under other tasks (e.g., independent confirmatory code analysis)	6 months	1 year before the first long-term core load[4] of higher burnup fuels and fuels with increased enrichment
4	Update guidance (as necessary) to support licensing and oversight functions for plants making modifications (if any) to accommodate higher burnups and increased enrichments	Completion of the items above	1 year	Before the core load
5	Update agency PRA models to reflect changes to the as-built, as-operated plant (if any) for relevant plants/models	Details of the plant modifications	1 year[5]	As needed to support the agency's risk evaluations

[4] Here, core load means the replacement of a large proportion (e.g., 50 percent or more) of the core.

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

Table A.7 PRA Activities for Higher Burnups and Increased Enrichments—Deliverables*

Title	Lead Time
Safety Evaluation contributions for TRs and LARs related to using fuels with higher burnups and increased enrichments	TBD
Report that documents results and recommendations from a SPAR pilot study	1 year before the first long-term core load of higher burnup fuels and fuels with increased enrichments
Updated guidance (e.g., risk-assessment standardization project guidance changes) to support licensing and oversight functions for plants making modifications (if any) to accommodate higher burnups and increased enrichments	Varies depending on the documents that require modifications
Updated agency PRA models to reflect changes to the as-built, as-operated plant (if any) for relevant plants/models	As needed to support the agency's risk evaluations

* The technical lead is the NRR Division of Risk Analysis, Probabilistic Risk Assessment Oversight Branch.

A.4 Task 4: Developing Independent Confirmatory Calculation Capabilities

Independent confirmatory calculations are one of the tools that the staff can use in its safety review of topical reports and license amendment requests. Confirmatory calculations provide the staff insight on the phenomenology and potential consequences of transient and accident scenarios. In addition, sensitivity studies help to identify risk significant contributors to the safety analyses and assist in focusing the staff's review.

RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," identifies the standard format and content of safety analysis reports for nuclear power plants, and NUREG-0800, "Standard Review Plan for the Safety Analysis Reports for Nuclear Power Plants: LWR Edition," (SRP) identifies the criteria that the staff should use to review licensee safety analyses. The NRC plans to continue to develop independent confirmatory analysis tools that support robust safety evaluations and provide insights into safety significant factors for burnup and enrichment extension. Vendor codes used to support analysis of fuel above existing burnup and enrichment limits will likely be based on smaller data sets than the data sets available for Zr-UO_2 fuel below existing limits. This will result in greater uncertainty in the results of the safety analyses and the margins to the specified acceptable fuel design limits. For these reasons, confirmatory calculation capabilities will be critical for generating confidence in the safety assessment of burnup and enrichment extension against all applicable regulatory requirements (see Section B.3 for more details). A confirmatory code can be used to independently quantify the impact of modeling uncertainties and support more efficient reviews with the potential for fewer requests for additional information. Finally, the experience and insights gained by developing an in-house code can be leveraged in reviews of externally developed models and methods, thus making reviews more efficient and effective.

The staff identified four technical disciplines needing calculation capability development to support TR/LAR safety reviews for burnup and enrichment extension: (1) fuel performance, (2) thermal hydraulics, (3) neutronics, and (4) severe accidents. The NRC has developed a suite of codes to analyze these disciplines, and they have been used successfully to support regulatory decision-making. Further development of these codes is appropriate to ensure that the NRC has the capability to analyze Zr-UO_2 fuel above existing regulatory burnup and enrichment limits. Having tools that the staff can use to analyze fuel with higher burnup and increased enrichment will be particularly important because applicants will use computational tools to demonstrate that they have met fuel safety acceptance criteria and because, in some cases, the properties and models for fuel at higher burnup and increased enrichment within the computational tools will be based on limited experimental data.

Code development activities for higher burnup and increased enrichment will be integrated and sequenced, as appropriate, with activities for ATF described in Section 10 of the ATF Project Plan. In particular, the NRC will participate in PIRT exercises for increased enrichment, perform scoping studies to identify code architecture and model updates needed, modify the codes based on outcomes of the increased enrichment PIRT and scoping studies, and perform assessments against available experimental data. Section 10 of the ATF Project Plan describes the approach NRC will take to update its codes to support confirmatory analysis for higher burnup and increased enrichment limits.