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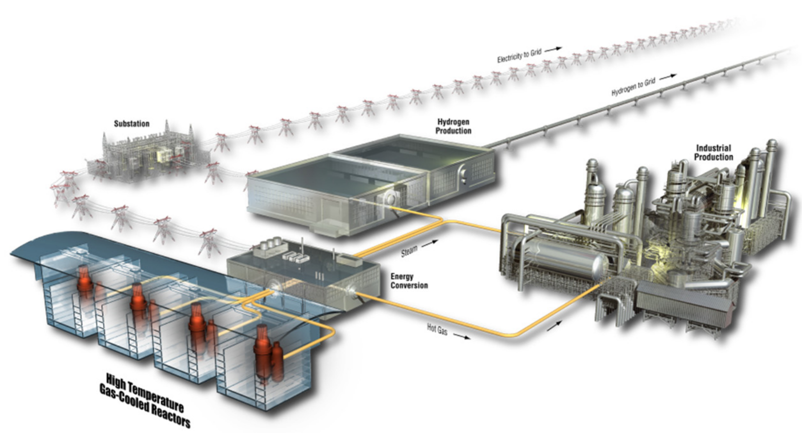
Licensing Modernization Project for Advanced Reactor Technologies: FY 2018 Project Status Report

September 2018



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SUMMARY

The promise of new nuclear technology and the future of commercial power in the United States (U.S.) are linked to the existence of an efficient and safety-focused regulatory review and licensing process. With an appropriate regulatory framework, reactor suppliers and regulators can design, license, and build advanced reactor units more efficiently and thereby help meet the growing need for clean and reliable energy.

To help address the challenge of maintaining compatibility between the regulatory environment and new commercial nuclear plant designs, the U.S. Department of Energy (DOE) is supporting an industry-led effort called the Licensing Modernization Project (LMP). This cost-shared initiative, started in 2016 and scheduled to complete in 2019, targets amendment to key elements of the U.S. nuclear power reactor regulatory framework to specifically address licensing barriers in advanced reactor concepts. The project focused on updating guidance for certain technical licensing requirements that are largely incompatible with non-light-water reactors (non-LWR) and establish a new pathway for design-safety evaluations and license-application development. Upon completion, the project will have created a new pathway, founded on modern probabilistic assessment techniques, that offers developers, suppliers, regulators, and owner-operators greater clarity and assurance in design and licensing decisions.

The LMP employs a team of advanced reactor technology and licensing subject matter experts working closely with U.S. regulators, affected industries, and interested members of the public. Led by Southern Company, the project is supported through a cost share arrangement with DOE. Technical contributions are provided by the Idaho National Laboratory (INL) Regulatory Development Technology Area, the Nuclear Energy Institute (NEI), and the U.S. Nuclear Regulatory Commission (NRC).

The LMP identified a suite of high priority issues that created significant uncertainty within the regulated non-LWR community. It was determined that much of this uncertainty could be retired by issuing updated licensing guidance founded on safety performance demonstrations and modern probabilistic methodologies. The success criteria for the project are:

- Generate sets of technology-inclusive (TI), risk-informed, and performance-based (RIPB) technical requirements, recommendations, and proposals that can be reviewed, amended, and adopted for use by NRC staff and industry. The proposals would create an optional-use regulatory framework without imposing additional (i.e., mandatory) requirements.

- Support the recommended LMP updates such that they can be endorsed by NRC and used by applicants within 5 years. This also supports the DOE advanced reactor development and deployment goal of completing licensing reviews for technically mature non-LWR concepts sufficient to allow construction to proceed by the early 2030s.

- Further overall programmatic objectives established by DOE's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative by resolving technology-inclusive policy issues that adversely impact regulatory reviews, siting, permitting, and licensing of non-LWRs. This would provide significantly more regulatory certainty for advanced reactor developers.

By the end of 2017, LMP released four draft technical "white paper" proposals that formed the foundation for a RIPB licensing structure that is broadly compatible with non-LWRs. Three of the proposals discussed techniques, justifications, and other considerations addressing selection of licensing basis events (LBEs), the classification of plant structures, systems and components (SSCs) with respect to safety functions, and an objective means of evaluating defense-in-depth (DID) adequacy. The fourth proposal reviewed existing probabilistic risk assessment (PRA) methods and suggested how these methods could be employed in a safety assessment.

By early 2018, the four papers had undergone initial review by industry and NRC staff and underwent consolidation into a draft "regulatory guidance document." From February 2018 through today, regularly scheduled work-level discussions between the LMP, industry, and NRC staff further refined draft document content and format to a near-final version of formal regulatory guidance.

Today, the LMP guidance document is fully compiled and ready for comprehensive technical review by the Advisory Committee on Reactor Safety (ACRS). Once ACRS reviews are completed (expected in December 2018), the document will be again updated, finalized as Revision 0, and submitted to NRC for formal public comment and subsequent endorsement. It is expected that NEI (on behalf of industry) will submit the completed LMP guidance document (designated as NEI 18-04) to NRC. Relatedly, NRC recently issued a draft agency endorsement document (DG-1353) that accepts the LMP guidance into the regulatory framework.

Formal endorsement of LMP guidance is expected before the end of 2019. In the interim, the LMP will continue to work with industry and national laboratory team members to provide the technical support needed to facilitate NRC reviews and update the guidance document. The LMP also plans to generate supplemental (i.e., non-NRC endorsed) guidance information for LMP process users and continue process demonstrations in the context of design-specific exercises and applications testing. Current planning suggests the LMP will conclude normal project work activities in 2019.

CONTENTS

FIGURES

TABLES

ACRONYMS

ACRS	Advisory Committee on Reactor Safety
ADAMS	Agency Document Access Management System (NRC)
AOO	anticipated operational occurrence
ARRTF	NEI's Advanced Reactor Regulatory Task Force
ART	Advanced Reactor Technologies
AT	analytical tools
BDBE	beyond design basis events
CFR	Code of Federal Regulation
DBA	design basis accident
DBE	design basis event
DID	defense-in-depth
DOE	U.S. Department of Energy
DOE-NE	DOE-Nuclear Energy
F-C	frequency-consequence
FDC	functional design criteria
FHR	fluoride high temperature reactor
FY	fiscal year
GAIN	DOE's Gateway for Accelerated Innovation in Nuclear
GFR	gas fast reactor
HTGR	high temperature gas-cooled reactor
INL	Idaho National Laboratory
LBE	licensing basis event
LFR	lead fast reactor
LMP	Licensing Modernization Project
LWR	light-water reactor
MSR	molten salt reactor
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NRC	Nuclear Regulatory Commission
NSRST	non-safety-related with special treatment
NST	no special treatment
NUREG	nuclear regulatory report
PB	performance-based

PRA	probabilistic risk assessment
R&D	research and development
RI	risk-informed
RIPB	risk-informed, performance-based
SFR	sodium fast reactor
SR	safety-related
SSCs	structures, systems, and components
TI	technology inclusive
U.S.	United States

Licensing Modernization Project for Advanced Reactor Technologies: FY 2018 Project Status Report

1. OVERVIEW

1.1 Purpose

Advanced (i.e., non-light-water) reactor technologies offer developers new opportunities to enhance the reliability, efficiency, and safety of nuclear power reactors through changes in fundamental design and operation. A variety of advanced design concepts are being developed that generally trend toward increased reliance on innovative, inherent, and passive safety features. Many of these features are substantially different from components now found in large light-water reactors (LWRs) that dominate the commercial fleet. Similarly, non-LWR suppliers are also pursuing market niches quite different from the regional baseload power generation sites typically associated with large LWR facilities.

Nuclear plant regulatory safety assessments have focused on LWRs for decades. Consequently, the United States (U.S.) regulatory framework (i.e., regulations, technical requirements, and related compliance guidance) governing nuclear plant design, construction, and operation is tailored to address large LWRs and LWR-derived concepts. This framework requires update to be technology-inclusive (TI), with commensurate reductions in associated compliance uncertainties, if non-LWR technologies are to contribute to the domestic energy supply.

The U.S. Nuclear Regulatory Commission (NRC) recognized the modernizing of key elements of the nuclear plant regulatory framework as essential to commercial success of advanced reactors. Many of these issues appear in the *NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness* [1]. Additional barriers are identified in NRC Vision and Strategy Implementation Action Plans [2,3].

The U.S. Department of Energy (DOE) is a facilitator for the development of innovative reactor technology [4]. New nuclear technologies typically require extensive and highly specialized research and development (R&D) programs to attain a stage of maturity that supports licensing and field construction of a technology demonstration platform. Because nuclear technology demonstration platforms are subject to NRC licensing requirements prior to starting construction, the precursor R&D for such units must adequately address regulatory requirements and policies early in the design. This means initial R&D planning must be well-informed with respect to applicable licensing requirements and safety-performance criteria.

Figure 1 illustrates a sequential relationship between the NRC licensing framework, technology R&D programs, and the deployment of a commercial advanced reactor.

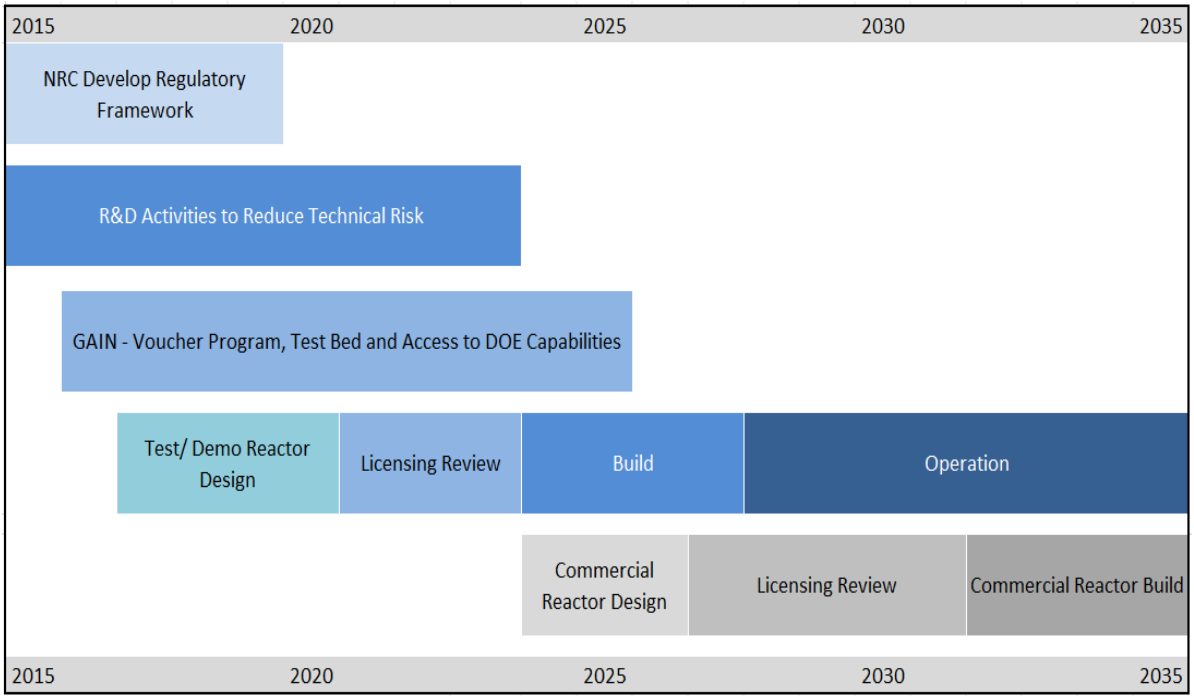

Figure 1. DOE support sequence for advanced reactor technology development.

DOE established the industry-led Licensing Modernization Project (LMP) to update key portions of the regulatory framework and allow advanced reactor deployments to move forward in ways similar to the Figure 1 depiction. The scope of this project, executed in conjunction with NRC and industry involvement, specifically targets assistance to non-LWR design and licensing. The remainder of this report further discusses the objectives, activities, and status of the LMP.

1.2 Background

Reactor-licensing safety assessments can be broken down into a variety of topical groupings that relate to one another based on safety performance and risk. At a fundamental level, these areas are evaluated for acceptability based on radiological dose risks presented to off-site members of the public. DOE chartered the LMP both to examine existing technical regulatory requirements related to the identification, evaluation, and management of advanced reactor accident initiators and sequences and to recommend and implement changes that create a new foundation upon which non-LWR plant safety can be assessed and maintained.

The LMP approached this task by systematically reviewing current technical regulatory requirements as they relate to emerging advanced reactor designs and synthesizing an approach that adapted their application to non-LWR paradigms. This approach would not diminish safety performance expectations as currently mandated by existing regulations. The adaptation would also be accomplished without incurring the long schedule delays typically associated with formal NRC rulemakings; this enables its availability for use by applicants within 5 years.

Project planning started in April 2016 using a small team of subject-matter experts in the areas of private-sector licensing and advanced reactor technology. A cost-share arrangement between the DOE Office of Nuclear Energy (DOE-NE) and LMP industry participants established project funding. Southern Company was designated the industry lead for the project; additional vendors/suppliers and owners/operators participated in various phases of project throughout the life of LMP. The LMP team actively solicited this level of stakeholder participation to ensure crosscutting issues, concerns, and insights were appropriately incorporated into project goals and objectives. At the request of Southern

Company, staff of the Idaho National Laboratory (INL) Regulatory Development Department and the Nuclear Energy Institute (NEI) supplied supplementary technical licensing support throughout the life of the project.

The industry-led LMP project structure represents a unique undertaking in regulatory-framework transformation. It is distinctive in that, while overall project leadership is provided by a single prospective reactor technology owner-operator (i.e., Southern Company), and nominally supported by DOE-NE and DOE labs, the project itself is scoped to build on earlier framework modernization efforts for the benefit of the entire advanced reactor stakeholder community. This community includes domestic advanced reactor designers and suppliers, utility owner-operators, regulators, and industry advocacy groups. Because project goals are to increase overall framework compatibility for all non-LWR concepts, rather than seek regulatory approval for a single proprietary design, the technology-inclusive nature of LMP work will provide much greater benefits and efficiencies to both regulators and reactor-technology developers.

Six classes of advanced reactor technologies were considered in the development of LMP scope:

- Sodium Fast Reactors (SFRs)
- Lead Fast Reactors (LFRs)
- Gas-Cooled Fast Reactors (GFRs)
- Modular High Temperature Gas-Cooled Reactors (HTGRs)
- Fluoride High Temperature Reactors (FHRs)
- Molten Salt Reactors (MSR).

While major design and safety characteristics of these technologies were considered during top-level project planning, the greater availability of (non-proprietary) details concerning HTGR, SFR, and (to a lesser degree) MSR designs meant those particular concepts received proportionally greater scrutiny from the work team.

2. LMP OBJECTIVE

As previously discussed, the primary objective of the LMP is to identify and revise high-value, crosscutting elements of the regulatory framework in order to increase compatibility with non-LWR design features and safety approaches. This objective was to be accomplished by issuing unambiguous new guidance that adapts existing LWR-oriented policies and technical requirements to the widest possible assortment of non-LWR applications. Furthermore, in addition to identifying and clarifying applicable regulatory requirements, the guidance would also provide for the use of modern, objective and proven analysis methods suited for assessing and demonstrating compliance with those requirements. To achieve the desired enhancements, this guidance would also require formal endorsement by NRC, thereby enabling its use by applicants in future design and licensing decisions.

A project engagement strategy supports the LMP action plan. This strategy benefited greatly from NRC staff willingness to interact directly with stakeholders to improve the clarity and usefulness of agency policies and requirements. Because the agency considers LMP activities “generic,” the staff provides support to LMP on an “off-fee” basis.

The transformation approach that emerged from the LMP analysis employs the following elements:

1. A series of robust, well-justified, related, and clearly actionable proposals that include identification of acceptable assessment methods, evaluation criteria, and sources of uncertainty. The proposals would be acceptable to industry and regulatory stakeholders and grounded in suites of proven

technical methods amenable to multiple advanced reactor types without incurring extensive modification, adjustment, or interpretation.

2. Integrating the various proposals into a single guidance document suitable for NRC review and subsequent endorsement as formal regulatory guidance. The guidance will be an optional pathway for non-LWR applicants to use within 5 years.
3. Guidance will increase clarity for developers and NRC reviewers, but will not erode public confidence in already-established regulatory criteria and assessment methods. Mature and proven assessment techniques and information would systematically and objectively identify risk contributors and evaluate consequences of a design.

An example of how new LMP guidance would enhance the advanced reactor licensing environment involves NRC regulation 10 CFR 50.34. This regulation requires:

> "*…analysis and evaluation … of the adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents.*"

Clear guidance for complying with this requirement is available to LWR applicants. This guidance includes detailed information on what LWR accident scenarios are acceptable for licensing safety review and what constitutes "adequacy" in systems, structures and components (SSCs) that perform a necessary safety function. However, safety review accidents scenarios are undefined for non-LWR designs and SSC adequacy definitions are much less mature with respect to advanced reactor applications. The guidance that emerges from the LMP effort would address this shortcoming by providing a systematic method by which all advanced designs can effectively identify licensing basis accidents and objectively classify SSCs that must function to prevent or mitigate those same event families.

Furthermore, since many non-LWR design features potentially important to safety have never undergone a successful licensing safety review, the SSCs associated with such features are without precedent and devoid of the detailed technical guidance applicants typically rely upon to remove compliance ambiguity [5]. The LMP has recognized the importance of this concern and determined that, if licensing uncertainty is to be meaningfully reduced, highly detailed technical method usage guidance and adequate training appropriate to the new licensing approach would be needed to aid initial users of the modernized assessment process.

Details concerning the LMP work scope were summarized in *Regulatory Risk Reduction for Advanced Reactor Technologies—FY 2016 Status and Work Plan Summary* [6]. Subsequent updates in the work plan were described in *Regulatory Risk Reduction for Advance Reactor Technologies: FY 2017 Framework Modernization Proposals and Status* [7]. Both documents elaborate on stepwise development of LMP technical proposals and evaluation methods that are:

- *Risk-Informed (RI)*. The methods provide systematic and robust consideration of the risk to the public during design and licensing.
- *Performance-Based (PB).* The methods facilitate clear and (to the extent practical) direct relation between advanced reactor performance and the requirements.
- *Technology-Inclusive (TI)*. Proposals and methods have consideration that enable and incentivize innovation across a broad spectrum of advanced reactor concepts.

While many LMP work activities identified in the fiscal year (FY) 2016 and FY 2017 project-status reports were modified in response to stakeholder feedback and emergent need, most adjustments were simplifications and consolidations of initially planned activities and work products. This project streamlining allowed acceleration of internal project schedules by about one year and moved the anticipated LMP end date from 2020 to 2019.

3. LICENSING MODERNIZATION PROJECT

3.1 Organization

The LMP operates based on:

1. A multi-faceted, industry-led work team (managed by Southern Company) responsible for interactions and discussion with reactor suppliers, owner-operator organizations, and NRC. Southern Company is a highly experienced, large LWR utility committed to bringing advanced reactor technology to commercial readiness. As a prospective applicant (i.e., an owner-operator) of an advanced reactor design, Southern Company engages the LMP industry team that it leads to ensure:
   a. Opportunity and impact analyses are performed on key regulatory elements and identify options that benefit the advanced reactor community. These opportunities are linked with current NRC requirements, policies, and guidance without creating additional compliance hurdles.
   b. Actionable recommendations and proposals are developed and tuned to address major gaps and uncertainties in the regulatory framework related to non-LWRs.
   c. The activities performed allow NRC staff to review and endorse LMP proposals for a modernized regulatory framework as regulatory guidance. The guidance will be an option future applicants can choose to utilize when licensing an advanced reactor design.
2. The NEI provides technical interface with representatives of the nuclear industry. NEI is a nuclear industry advocacy group that has working relationships with numerous member organizations and the NRC. NEI is capable in this regard because it regularly represents advanced reactor developers and owner-operators through its Advanced Reactor Regulatory Task Force (ARRTF). The NEI ARRTF charter represents affiliate members before NRC and the public in matters of regulatory concern, thereby offering a single voice for industry when dealing with technical and policy concerns. LMP objectives are critical to the ARRTF and all LMP proposals are subject to review by ARRTF members prior to release.
3. The Regulatory Development Area of the Advanced Reactor Technologies (ART) program, located at INL, provides additional technical input and stakeholder interface support. INL also provides financial and project-communication liaison between industry and DOE.

3.2 Proposal Development

The LMP team identified three core technical proposals upon which a new TI-RIPB licensing process could be established. Areas of need consisted of: (1) details concerning how to identify, systematically and reliably, licensing-basis events (LBEs); (2) systematic methods by which physical plant SSCs potentially important to safety can be identified and classified; and (3) ways by which defense-in-depth (DID) prevention and mitigation measures can be demonstrated as adequate and acceptable. Furthermore, these proposals had to be incorporated into a unified assessment approach in order to provide the robustness and consistency needed for both plant design reviews and independent safety assessments. More specifically, the approach had to ensure that:

- The LBEs selected for use in safety assessments adequately cover the range of hazards to which a specific design would be exposed and properly reflect the failure modes appropriate to that design.
- Safety functions are defined in terms of successes and failures of SSCs along the selected LBEs, and they are adequately capable, reliable, diverse, and redundant across layers of defense in the design.
- The safety functions and SSCs have measurable performance criteria for their capabilities and reliabilities to prevent and mitigate accidents with adequate performance monitoring.

- The philosophy of DID is incorporated in both the design and relevant programmatic features. These elements must be included in the license application, along with outcomes of evaluations on DID adequacy.
- Sufficient and integrated design decisions trade-off plant capabilities and programmatic capabilities based on risk-informed insights with reasonable assurance of adequate protection.
- The scope and level of detail for plant SSCs and programmatic controls are included and described at levels commensurate with their safety and risk significance.

An additional LMP proposal would guide users in the application of probabilistic risk assessment (PRA) methods that supported the new evaluation approach. This application of PRA must be capable of addressing first-of-a-kind plants that may consist of two or more reactor modules, as well as non-core sources of radioactive material.

Figure 2 identifies how the LMP TI-RIPB evaluation scheme would relate to other key technical elements important to advanced reactor licensing. The figure also highlights a major benefit of the process by illustrating the ability to generate risk (i.e., frequency-consequence) based information that can be exported to help develop other plant-wide safety plans and risk management strategies.

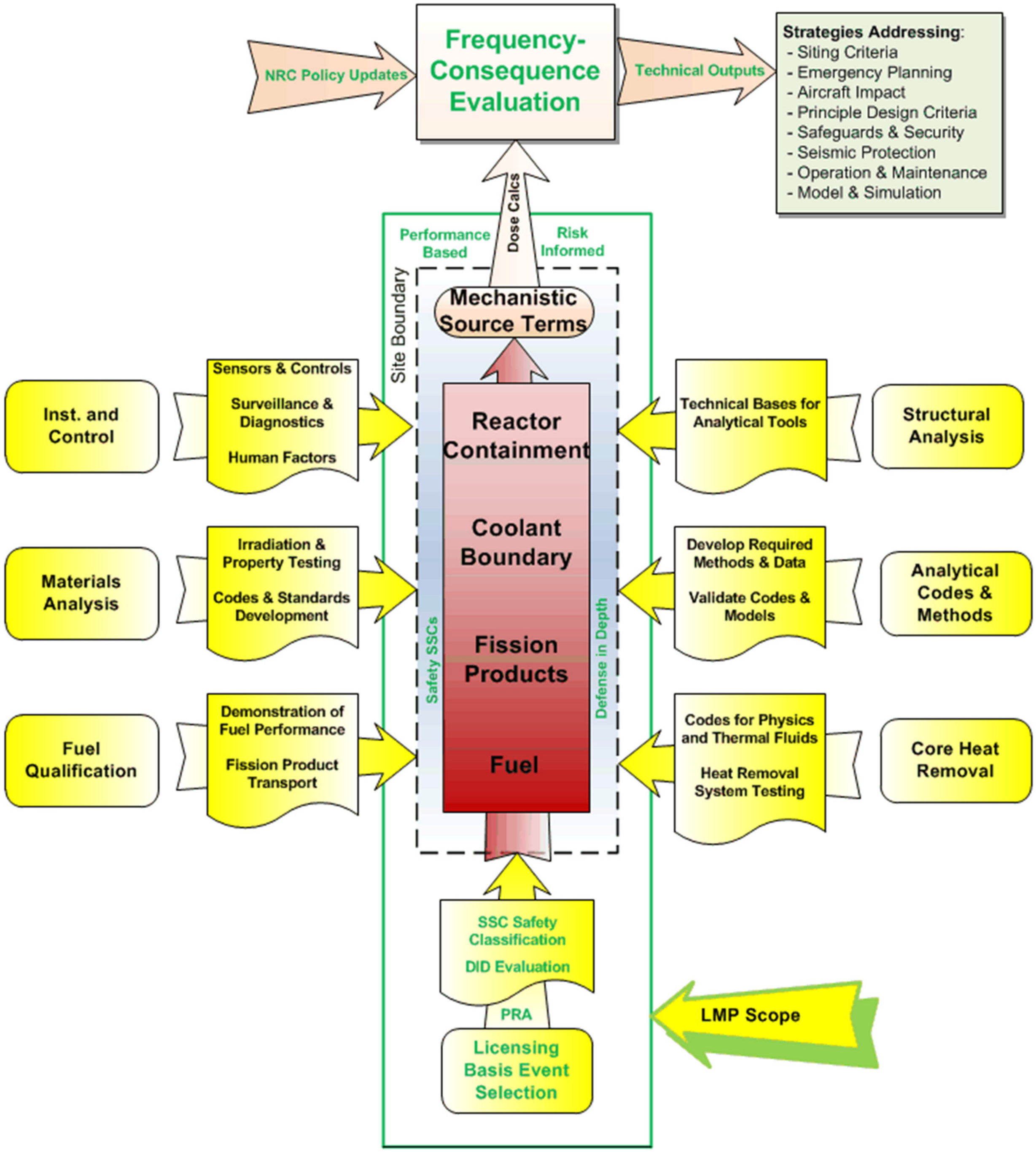

Figure 2. Licensing elements addressed by LMP.

LMP proposal development began in early 2017 in the form of four “stand-alone” white papers. Highly detailed working drafts of the white papers were written to serve as the basis for subsequent stakeholder reviews and to gather feedback needed to refine the proposals into preliminary regulatory guidance. After initial comments were collected on white paper contents, key information would be extracted from the (updated) proposals and consolidated into a single document. Once the guidance document was drafted, further refinements would be made because of additional iterative reviews. Once those reviews were completed, LMP planned to submit a final version to NRC for formal agency endorsement.

Project plans and schedules were set to provide for the collaborative engagements needed to refine white paper content and consolidate them into a condensed document. Schedules were set such that white paper reviews would occur in parallel and (somewhat) independently from one another in order to shorten timelines and more effective utilize limited project labor.

White-paper development comprised, in chronological order:

1. A technology-inclusive LBE selection process
2. A proposal on how existing PRA methods could be used in early design and licensing decisions
3. An approach for classifying plant SSCs with respect to their contribution and importance to safety
4. A quantifiable means by which the adequacy of DID measures could be established, demonstrated, and preserved.

LMP proposals drew extensively on earlier regulatory white papers generated by DOE's Next Generation Nuclear Plant (NGNP) project [8]. However, the LMP expanded and updated NGNP information by adding more-recent technical subject matter and incorporating elements that enabled more technology neutral applications.

All white papers extensively reviewed the history and justifications underlying the use of RIPB criteria in-lieu of prescriptive requirements. Specific performance goals were suggested, where appropriate, and regulatory precedents, existing policy decisions, established safety assessment methods, and available evaluation tools were used to the fullest extent possible. A thorough regulatory analysis accompanied each white paper before reviews were conducted and areas needing update were highlighted.

Drafts of the white papers were submitted to industry (via the NEI ARRTF) for technical review and comment. Thereafter, drafts were updated and subsequently transmitted to NRC staff and the public for additional feedback. Once initial feedback from NRC and public commenters were received, the LMP extracted and consolidated white paper information into a (draft) consolidated guidance document.

The following subsections provide further details about the content and status of each LMP white paper.

3.2.1 Licensing Basis Event Selection

The LBE-selection white paper lists relevant regulatory policies and guidance concerning the identification of LBEs relative to advanced reactor licensing [9]. The paper proposed a highly detailed TI methodology for selecting and classifying LBEs that includes design basis accidents (DBA). Other issues important to RIBP licensing evaluations were also noted.

The LBE-selection white paper aimed to:

- Secure NRC agreement on the proposed LBE-selection approach for incorporation into an appropriate regulatory guidance document
- Identify issues and topics having a potential to influence the selection and evaluation of advanced reactor LBEs, including anticipated operational occurrences (AOOs), design basis events (DBEs), beyond design basis events (BDBEs), and DBAs.

The white paper expanded upon information, justifications, and regulatory feedback received from the NGNP LBE Selection White Paper [10]. Amendments to NGNP information addressed technologies other than modular HTGRs. The LMP LBE-selection proposal also modified the NGNP frequency-consequence (F-C) curve, which is a major consideration in the LBE-selection process and a basic evaluation criterion.

The LBE-selection proposal also elaborates on how events would be derived using both deterministic and probabilistic elements of risk-informed decision-making. The scope covered the full spectrum of events considered in a safety evaluation. Four major LBE categories, other than daily (normal) operations, established under the approach are:

1. *Anticipated operational occurrences* encompass planned and anticipated events. The radiological doses from AOOs are required to meet normal operational public-dose requirements. AOOs are utilized to set operating limits for normal operation modes and states.
2. *Design-basis events* contain unplanned off-normal events not expected in the plant's lifetime, but which might occur in the lifetime of a fleet of plants. DBEs are the basis for the design, construction, and operation of SSCs during accidents.
3. *Beyond-design-basis events* are rare off-normal events of lower occurrence frequency than DBEs. BDBEs are evaluated to ensure that they do not pose unacceptable risks to the public.
4. *Design-basis accidents* for license application Chapter 15, "Accident Analyses," are derived deterministically from DBEs by assuming that only SSCs classified as safety-related are available to mitigate consequences. The public consequences of DBAs are based on mechanistic source terms and are conservatively calculated. The conservatively estimated dose of each DBA must meet the 10 Code of Federal Regulations (CFR) 50.34 consequence limit at the Exclusion Area Boundary.

A step-by-step process for selecting LBEs was prescribed in the LMP white paper. The process employs clearly stated parameters that are systematic, reproducible, sufficiently complete, available for timely input to design decisions, TI-RIBP, and consistent with current and applicable regulatory requirements. Example applications were provided for a modular HTGR and a pool-type liquid metal-cooled fast reactor to demonstrate the LBE selection approach.

The LBE selection approach was introduced to NRC staff during a February 2, 2017 public meeting (see NRC's website and Agency Document Access Management System (ADAMS) Accession No. ML17037D371 for background information). Concurrent with this introduction, the draft LBE Selection white paper reviewed by industry and updated in response to feedback. Another public meeting with the staff was held on March 22, 2017 (ADAMS Accession No. ML17086A419) during which additional details were provided on the overall LMP licensing approach. In April 2017, a work draft of the LBE selection proposal (ADAMS Accession No. ML17104A254) was transmitted to NRC staff for initial review. Additional discussions followed during public meetings held on May 3–4, 2017 (ADAMS Accession No. ML17130A782) and June 22, 2017 (ADAMS Accession No. ML17177A244). Staff questions and comments were transmitted in the form of written comments (ADAMS Accession No. ML17145A573), a table showing the relationship between analyzed events and other topics and regulations (ADAMS Accession No. ML17145A570), and in a redline strikeout markup of the white paper (ADAMS Accession No. ML17145A574).

Other than a project progress update presented to the staff during a November 2, 2017 regulatory-process-improvement public-stakeholder meeting (ADAMS Accession No. ML17310B495), formal response to initial staff feedback was delayed pending completion of LMP proposals dealing with PRA use, SSC classification, and determination of DID adequacy. All proposals were completed in late 2017, and interactions to resolve LBE selection comments resumed in January 2018.

3.2.2 Use of PRA in Licensing

The TI-RIPB assessment process relies on well-established PRA methodologies. The technique can be used both in plant design and to support licensing decisions. Furthermore, PRAs can be applied early in design development and continue to be used through design maturation and the operational life of the plant. Precisely how PRAs are employed in this capacity is the subject of a LMP white paper [11].

Objectives of the LMP PRA white paper consist of:

1. Identify similarities and differences between the LMP approach to using PRA and the approach that has been used in LWR applications
2. Identify key technical issues that must be resolved for successful application of PRAs to advanced non-LWRs
3. Describe an approach that uses available guides, standards, and peer-review processes to assure technical adequacy of the PRA
4. Define a means to develop the PRA so it can be used to provide necessary inputs to the selection of LBEs, as well as provide information that aids in the safety classification of SSCs, the formulation of special-treatment requirements, and performance of risk-informed evaluations of defense-in-depth
5. Describe an approach to PRA treatment of integrated risk from operation of a multi-module reactor plant.

The technical approach and applications presented in the white paper enable PRAs to serve as an essential support mechanism for the licensing framework because they facilitate:

1. Evaluations of design alternatives that clearly incorporate risk insights into the design
2. New probabilistic inputs to the definition of a safety function associated with SSCs in the prevention and mitigation of event sequences and accidents
3. Probabilistic inputs to the selection of LBEs
4. Probabilistic input to the selection of safety-related SSCs
5. Inputs to the definition of special-treatment and design requirements regarding performance, capability, and reliability of additional SSCs used in the prevention and mitigation of event sequences and accidents
6. The basis for risk-informed evaluation of DID.

Use of PRA in licensing is expected to be far ranging and to emphasize the systematic application of probabilistic insights. The PRA white paper also offers recommendations to avoid delays in addressing external hazards, embraces the full quantification of associated uncertainties, and heeds lessons learned from the Fukushima Daiichi accident.

The concept of using PRA techniques in advanced reactor licensing was introduced to NRC staff during a public meeting held on May 4, 2017 (ADAMS Accession No. ML17130A782). The white paper was reviewed by industry and updated. A working draft of the PRA white paper (ADAMS Accession No. ML17158B543) was transmitted to NRC staff in June 2017, for initial review and feedback. Additional discussions about PRA use occurred during a public meeting held at NRC headquarters on June 22, 2017 (ADAMS Accession No. ML17177A244) and during in a drop-in meeting on July 7, 2017. Related staff questions and comments concerning PRA use were communicated to the LMP in August 2017 (ADAMS Accession No. ML17233A187).

A public meeting (ADAMS Accession No. ML17272A141) was held to discuss questions received from the staff on September 28, 2017, but detailed responses were postponed pending completion of SSC classification and the determination of DID adequacy proposals. All proposals were completed in late 2017, and formal response to PRA comments began in January 2018 in connection with guidance document development.

3.2.3 SSC Classification

An SSC white paper addressed the classification and performance criteria of SSCs potentially important to safety [12]. The paper identified technical issues related to a proposed SSC safety-classification scheme and cited the requirements necessary to support SSC safety-function performance and prevent and mitigate LBEs. Requirements include those that provide a necessary capability to perform a mitigation function and meet reliability requirements that preclude LBEs with more severe consequences.

The SSC-classification white paper sought to:

- Describe an approach to SSC safety classification compatible the LMP framework
- Present a means for determining risk significance and safety significance of SSCs
- Discuss the roles of SSC reliability and capability in the prevention and mitigation of accidents
- Present a top-down process for developing functional design criteria (FDCs) and lower-level design criteria for implementation of required safety functions of SSCs
- Prescribe a process for developing special treatment requirements concerning performance of SSC functions in the prevention and mitigation of LBEs
- Reference relevant supporting regulatory guidance, precedents, and available information concerning proposed approach implementation
- Identify key technical issues associated with the proposed approach
- Provide linkage between LMP proposals dealing with PRA development, LBE selection and evaluation, and DID-adequacy evaluation

Safety-classification categories were developed from information originally presented in the NGNP white paper on SSC safety classification [13]. The information was supplemented with additional insights drawn from 10 CFR 50.69.

Briefly stated, the LMP proposed a SSC classification basis was fashioned around the following categories:

1. Safety related (SR):
    - SSCs selected by the designer to perform a required safety function and mitigate consequences of DBEs to within the LBE F-C evaluation target and to mitigate DBAs that only rely on the SR SSCs to meet the dose limits of 10 CFR 50.34 using conservative assumptions
    - SSCs selected by the designer and relied on to perform required safety functions that prevent the frequency of BDBE with consequences greater than the 10 CFR 50.34 dose limits from increasing into the DBE region and beyond the F-C target
2. Non-safety-related with special treatment (NSRST):
    - Non-safety-related SSCs relied on to perform risk-significant functions. Risk-significant SSCs are those that perform functions that prevent or mitigate an LBE from exceeding the F-C target or make significant contributions to the cumulative risk metrics selected for evaluating the total risk from all analyzed LBEs
    - Non-safety-related SSCs relied on to perform functions requiring special treatment for DID adequacy
3. Non-safety-related with no special treatment (NST):
    - All other plant SSCs (with no special treatment required)

Under the proposed approach, safety-significant SSCs include all SSCs classified as SR or NSRST; no NST SSC would be considered safety significant. The RIPB SSC performance and special treatment requirements identified in the document for SR and NSRST SSCs are appropriate to provide reasonable confidence in SSC capabilities and reliabilities consistent with the F-C target and the regulatory dose limits for DBAs.

The LMP introduced the SSC classification concept to NRC staff during a public meeting on September 28, 2017 (ADAMS Accession No. ML17272A141). Concurrent with that meeting, the white paper underwent review by industry and updated accordingly. In October 2017, a working draft of the updated white paper (ADAMS Accession No. ML17290A463) was transmitted to NRC staff for review. Related staff questions and initial comments concerning the proposal were transmitted back to the LMP in November 2017 (ADAMS Accession No. ML17319A210).

Formal response to staff feedback was delayed pending completion of the remaining white paper on determining DID adequacy. The DID proposal was completed in December 2017, and responses to SSC-classification comments were developed in conjunction with the January 2018 initiation of guidance document development.

3.2.4 Defense-in-Depth

Defense-in-depth is a longstanding safety philosophy applied to all nuclear plant designs. However, definitive regulatory guidance for evaluating and confirming the adequacy of DID mitigations is lacking. To address this source of uncertainty, the LMP developed a DID adequacy evaluation approach consistent with historic philosophies, NRC policies, and insights from Nuclear Regulatory Report (NUREG)/KM-0009, *Historical Review and Observations of Defense-in-Depth*, and related industry standards like IAEA's Safety Report Series No. 46, *Assessment of Defense in Depth for Nuclear Power Plants* [14, 15].

The LMP white paper describing DID-adequacy evaluations examined the purpose, history, and policies related to DID and identified applications available for use at nuclear reactor facilities [16]. Specific objectives of the white paper were:

- Establishing alignment with DID philosophy definitions and describing how multiple layers of defense can be deployed to confirm DID adequacy.
- Describing how protective DID strategies are used to define the DID attributes incorporated into plant capabilities that support each layer of defense. Resolution of general protective strategy concepts into sets of DID attributes is necessary to support the objective evaluation of DID adequacy. These DID attributes are reflected in plant design features, reliabilities, and capabilities of SSCs that include fission-product barriers contributing multiple, functionally independent layers of defense in the prevention and mitigation of accidents.
- Summarizing programmatic attributes of DID to provide assurances that DID plant design capabilities are realized during the entire plant design lifecycle.
- Discuss the role of programmatic DID attributes to compensate for uncertainties, human errors, and hardware failures.
- Identify the importance of defense against common-cause failures and the need to minimize dependencies among layers of defense.
- Presenting guidelines for evaluating and establishing a DID adequacy baseline.
- Providing agreement on how DID adequacy can be achieved among those responsible for designing, operating, reviewing, and licensing advanced non-LWRs.

Using LBE scenarios and SSC-classification proposals, in conjunction with RIBP definitions, as a frame of reference, the LMP developed a set of DID practices for use in different types of safety decision-making. A technical basis for DID adequacy was presented along with strategies for RIPB improvements achieved through design, safety capabilities, and programmatic controls. When implemented, the proposed DID approach should provide a more objective means to answer the important question for a specific design: When is enough, enough?

The LMP proposal was crafted to assure adequate application of DID measures with respect to public protection from radiological exposure due to accidental release. However, the robust nature of the approach is expected to benefit other types of DID adequacy determinations beyond those associated with radiological protection.

An introduction to the DID approach was delivered to the staff during a November 1, 2017 drop-in meeting. Concurrent with that meeting, industry representatives reviewed and provided comment on the content of the draft white paper. The DID adequacy determination approach was then presented to the staff during a public meeting on December 14, 2017 (ADAMS Accession No. ML17354B219). A draft version of the white paper (ADAMS Accession No.ML17354B174) was transmitted to the staff at that time. Staff questions and comments relating to the proposal were received in January 2018 (ADAMS Accession No. 18024A595).

LMP responses to DID feedback were merged with other pending responses for prior white papers. A follow-up interaction on DID adequacy, along with an overall LMP status update, was provided to the staff during a February 1, 2018, public stakeholder meeting. (ADAMS Accession No. ML18036A897).

Release of the draft DID white paper marked the conclusion of initial LMP proposal development. Beginning in January 2018, the project shifted emphasis to development of a guidance document. Guidance development started by extracting key technical requirements and other information suitable for inclusion in a regulatory guide from the white papers and adjusting content and format. The following subsections further discuss draft guidance document development.

3.3 Licensing Guidance Document

3.3.1 Proposal Integration

The licensing guidance document was envisioned to summarize the foundational RIPB and more implementation-focused proposals made by LMP that support advanced reactor safety design and assessment. The format and content of the document conforms to NRC regulatory guidance standards and, once endorsed by NRC, would offer applicants a new pathway to demonstrate compliance with requirements, standards, and policies prescribed by the agency.

LMP began the guidance document in January 2018 with an annotated outline of the expected work product. The outline focused on capturing topics related to the identification, quantification, and management of sources of design and operational risk to the public. Excessive subject-matter discussions like process-development histories and justification details on methodologies were avoided since those implementation details are reflected in detail in the four associated white papers.

The contextual relationship of the LMP approach and licensing basis as presented in the guidance document is shown in Figure 3.

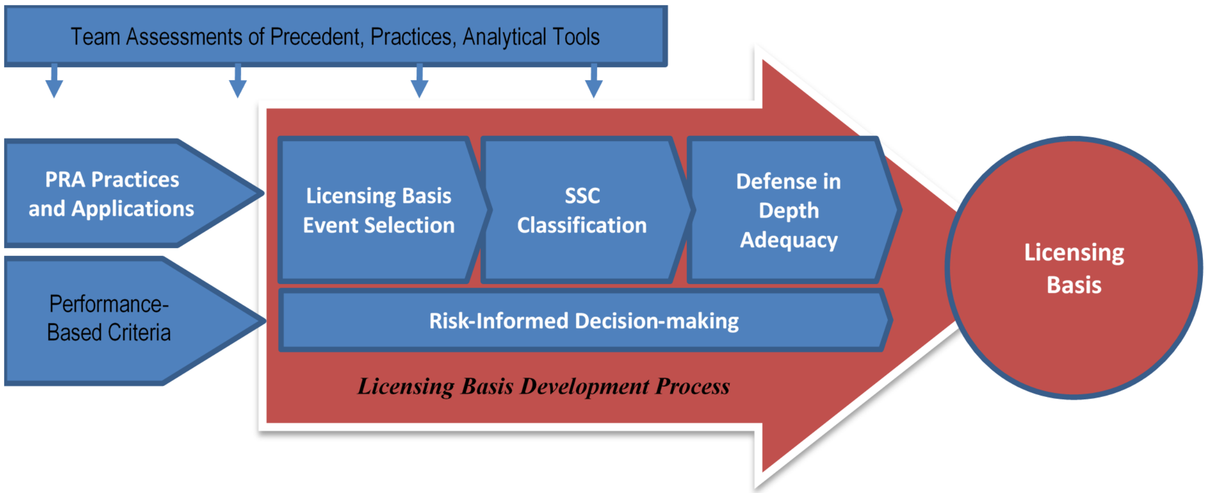

Figure 3. Primary elements of the TI-RIPB licensing framework.

The document providing licensing-basis guidance by integrating LMP-proposed methodologies to present:

1. A versatile and generic process for selecting risk-informed, performance-based LBEs
2. Clarity on how established risk-analysis techniques (i.e., PRA) can be acceptably used as part of risk-informed decision-making both early in and continuing through plant design life cycles
3. A method by which plant SSC can be systematically evaluated, classified, and assessed with respect to their real or potential contribution to safety
4. Defined objectives and reproducible means by which the adequacy of DID safety measures can be established and preserved throughout the entire plant design and operational life cycles.

The LMP shifted work away from initial proposal development to guidance document generation in early 2018. However, the project maintained attention to updating the original draft white paper. Updating white papers to reflect final guidance document content is an important project work activity because these documents are expected to provide users with additional background information, supplemental technical-basis material, and operational advice needed to implement the approach. The LMP plans to update the four white papers and release them at the conclusion of the project to assist users in process implementation; the white papers will not be submitted to NRC for endorsement as regulatory guidance.

3.3.2 Stakeholder Engagement

Working meetings to bring guidance document content to maturity occurred through 2018. Essential participants in this effort included LMP, NEI, and NRC staff tasked with refining LMP proposals and confirming which RIPB material (extracted from the white papers) merited inclusion in the guidance document. The general sequence of engagement in consensus development (including the table-top exercises further discussed in Subsection 3.3.3) is shown in Figure 4.

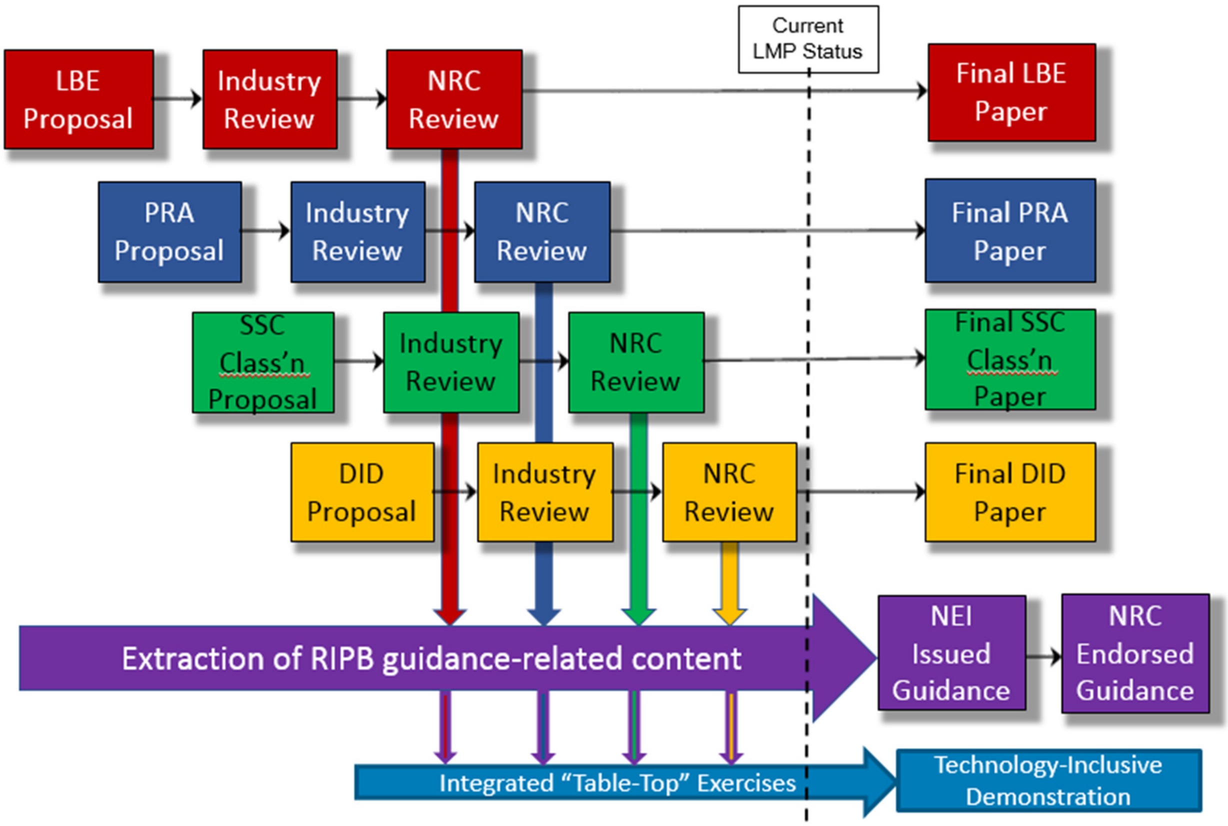

Figure 4. LMP engagement and review process.

Industry reviews of the guidance document were again facilitated through the NEI ARRTF. Some ARRTF members are now actively developing licensing applications for their proprietary design; thus, their input is an important component in the initial LMP process. Industry participation is expected to continue throughout 2019 as the guidance document undergoes review and acceptance processes administered by NRC.

Face-to-face working meetings were the primary means by which participant communicated their analytical findings and established initial consensus. All meeting were open to public participation and supplemented by informal drop-in meetings, teleconferences, and emails where necessary to support progress. Table 1 lists the primary work meetings that significantly contributed to guidance document development.

Table 1. LMP/NRC Development Meeting Summary

Date	Meeting	Subject
Feb 14, 2018	LMP/NRC guidance document development	Discussions explored guidance document format, general technical content, and expected levels of detail. Potential pathways for NRC endorsement were reviewed and a preferred pathway identified.
Apr 5-6, 2018	LMP/NRC guidance document development	Review of staff feedback on the consolidation approach for the four LMP white papers. Discussion continued concerning initial guidance document content. Areas of technical consensus were identified and outstanding priority issues such as specific evaluation criteria

Table 1. (continued).

Date	Meeting	Subject
		(requiring further development) were noted. The meeting reviewed development schedules and discussed support needs for future process implementation.
Jun 5-6, 2018	LMP/NRC guidance document development	In-depth review of staff comments on the emerging guidance document. Potential changes in key F-C curve values were discussed as were attributes of initiating events and event-sequences. Preparations were made for briefing to Advisory Committee on Reactor Safety (ACRS) Future Plant Designs Subcommittee.
Jun 18, 2018	NRC staff training	LMP members delivered process familiarization training to staff on the RIPB process (NRC White Flint offices). Feedback on the licensing approach was provided by attending staff.
Jun 19, 2018	ACRS Future Plant Design Subcommittee/LMP/NRC review meeting	LMP introduced the proposed licensing approach to the ACRS Subcommittee. The agenda emphasized overall process structure and methodology components; discussions on specific evaluation criteria values remained tentative pending further staff analysis. Staff offered insights on policy implications of the LMP approach; ACRS Subcommittee provided initial feedback on Version M of the draft guidance document (provided to NRC on May 27, 2018).
Aug 21, 2018	LMP/NRC guidance document development	Workshop focused on development of LMP's draft guidance document and review of a draft NRC regulatory guide. The agenda included resolution of June NRC and ACRS comments, glossary clarifications, DBE/DBA considerations, and schedule finalization.

Another important source of feedback came from periodic NRC public-stakeholder meetings on advanced reactor process improvement. These regularly scheduled meetings, sponsored and conducted by NRC staff, focused on regulatory-process improvement opportunities specific to advanced reactor designs. More information on these meetings, including meeting slides and summaries, can be found on the NRC website at https://www.nrc.gov/reactors/new-reactors/advanced.html#stakeholder.

3.3.3 Table-top Demonstrations

As LMP white paper proposals underwent development, prospective licensing-approach users within industry (along with NRC staff) expressed interest in modeling important process elements against actual proprietary designs. Such demonstrations were not explicitly incorporated into the original LMP work scope and are not considered essential to guidance document development or acquisition of NRC endorsement. However, performance of table-top exercises was viewed as an opportunity to collect supplemental insights about overall approach implementation and increase prospective user familiarity with the emerging process. Furthermore, demonstrating process applications against contemporary non-LWR safety approaches would also serve to increase stakeholder confidence in the technology-inclusive attributes of the new licensing approach and likely accelerating deployment timeframes and efficiencies.

From early 2018 and continuing to the present, the LMP has supported industry demonstrations of the advanced reactor licensing process. These exercises are independent from one another and performed in the context of a proprietary reactor design currently under development for the commercial energy market.

Developers interested in sponsoring an LMP licensing exercise evaluation of their design process must:

1. Provide resources and support that adequately enables preparation for and performance of an LMP table-top level exercise
2. Provide design data and information for their concept appropriate to the exercise scope and test parameters; these data must allow for a public discussion during exercise work meetings
3. Allow publication of a work-products summary that captures exercise findings and conclusions; this summary would be shared with NEI ARRTF and NRC staff.

Findings and observations resulting from these demonstrations are to be reviewed by the LMP team and may provide a basis for refinement within the guidance document, finalized white papers, or both.

Two table-top demonstrations have been performed thus far: (1) the X-energy pebble-bed HTGR (April 2018), and (2) the GE-Hitachi integral SFR (now near completion). A report on X-energy results is available while GE-Hitachi results are being compiled. [17] Planning for additional exercises are underway that may lead to examinations of an MSR and a small “micro-reactor” design.

3.3.4 Guidance-document Status

As of mid-September 2018, the LMP has compiled a fully reviewed draft guidance document and is preparing to submit it (as a draft) to NRC for comprehensive reviews by the ACRS Subcommittee on Future Plant Designs and the full ACRS Committee. These reviews are tentatively scheduled to occur in October and December 2018, respectively. Comments and observations potentially significant to the NRC acceptance and endorsement may result from these ACRS reviews. The LMP intends to update the draft guidance document as necessary in response to ACRS feedback and then transmit it to NEI for acceptance into their external publication hierarchy as NEI 18-04. NEI, as a representative of industry stakeholders, will then resubmit the finalized LMP guidance document as an NEI document to NRC. Correspondence that formally requests agency review and endorsement of NEI 18-04 as a regulatory guide will accompany this resubmission.

While all forms of stakeholder feedback will continue to be received by LMP and incorporated into the draft guidance document during forthcoming ACRS reviews, LMP focus is now shifting away from periodic staff-level work meetings towards the facilitation of NRC management and public reviews and comment periods. The path forward for the LMP over the next year is discussed in Subsection 3.4.

It is worth noting here, however, that the value of the LMP effort has been recognized as an important step in improving timely and efficient advanced reactors reviews while continuing to protect public health, safety and security. For example, on February 20, 2018, three ex-NRC commissioners (i.e., Hon. George Apostolakis, Hon. Jeffrey S. Merrifield, and Hon. Richard A. Meserve, each serving in an advisory capacity to the LMP) sent a project assessment letter to Mr. Stephen Kuczynski, Chairman, President, and Chief Executive Officer of Southern Nuclear Operating Company. In it, the authors “enthusiastically endorsed the effort” and expressed their belief that the project, focused on systematically and predictably establishing a process for early resolution of fundamental technical issues, can indeed reduce uncertainty in the development of a new design. The letter further acknowledged that the project actively addresses gaps in several foundational areas where current regulations and guidance are either silent or inadequate for non-LWR designs. These ex-commissioners, having met with numerous stakeholders regarding the LMP (including individuals at NRC), encouraged continuation of this beneficial work.

Similarly, on February 21, 2018, Mr. Frederick Brown, Director of NRC Office of New Reactors, transmitted a letter to Mr. Stephen Kuczynski, Chairman, President, and Chief Executive Officer of Southern Nuclear Operating Company, acknowledging the useful interactions between LMP and NRC staff. The communication also underscored the importance of the LMP effort in helping set the stage for the development more formal guidance (ADAMS Accession No. ML18047A149).

A response to Mr. Brown's letter was sent on March 9, 2018 from Mr. Kuczynski. In this correspondence, it was observed that

> *"…the LMP's focus on developing a systematic and predicable process for early resolution of fundamental technical issues in the licensing of advanced reactors will reduce uncertainty in the development, design, and eventual licensing of such designs."* (ADAMS Accession No. ML18103A213)

At this time, the LMP licensing safety-analysis approach is firmly established and not expected to change substantially during forthcoming regulatory reviews or the NRC endorsement process. However, individual assessment criterion values may be adjusted from values proposed by the LMP as a consequence of comments received from NRC. The LMP is expected to continue collaborations with NRC and other stakeholders throughout FY 2019 and incorporate feedback that assures appropriate consensus is maintained.

3.4 LMP Completion

3.4.1 Guidance-document Completion

NRC endorsement of the proposed licensing approach is necessary if the primary project objective—establishing a more-effective means of satisfying applicable regulations for non-LWRs that is acceptable to the NRC—is to be achieved. After two years of focused analytical effort and dialogue among industry, the NRC, and the public, a guidance document meeting this goal has been crafted and is near readiness for submission to NRC for adoption. Key considerations concerning this submission include:

- The guidance document provides a stand-alone foundation for a new TI-RIPB licensing approach. It specifies technical methods and requirements proposed for use by both industry and regulators. No additional documents will require regulatory approval prior to using the approach. While external documents are cited in the document, these citations are meant to provide history, context, and information on specific tasks, as well as pointers to existing and applicable requirements and guidance.
- The RIPB techniques contained in the guidance document are based on information and methods derived from well-established research and testing activities stretching back decades and continuing to the present. No additional R&D of the methodology is necessary prior to NRC endorsement. While the methods may be new for use in a licensing action, the techniques and methods themselves are proven and not experimental.
- NEI has tentatively designated the guidance document as NEI 18-04. A complete draft of NEI 18-04 is scheduled for release in late September 2018. This draft will be reviewed by ACRS and formal recommendations made in the form of a letter. Once ACRS feedback has been addressed, a final Revision 0 version of NEI 18-04 (i.e., an approved NEI document) will be released.
- Industry, through the auspices of NEI, will transmit the Revision 0 guidance document to NRC. A letter formally requesting regulatory endorsement will accompany that transmittal.
- NRC endorsement of NEI 18-04 will be facilitated using administrative procedures deemed appropriate by the agency (such as a NUREG or Regulatory Guide). At this time, the staff has drafted a Regulatory Guide (DG-1353) for use as the likely tool in agency endorsement. A SECY paper has also been drafted by the staff on the proposed action to allow policy inputs by the Commission.

- Supplemental guidance that supports the use of the LMP licensing approach may be needed in the future. This includes developing operational details about RIPB process implementation as well as how the process relates to other elements of the still-evolving advanced reactor regulatory framework. Development of supplemental regulatory guidance is not currently in the LMP scope; subsequent collaborative efforts are needed to develop such guidance.
- The LMP framework modernization approach did not incur a rulemaking action. Such rulemaking typically requires substantial schedule and resource commitments that were not in the near-term interest of the advanced reactor community. Immediate implementation of the LMP licensing approach presumes that appropriate exemptions or departures from current regulations and requirements will adequately facilitate process deployment and use. Should it later be determined that rule promulgation is required, the NRC will be responsible for initiating such action.

NRC is the lead agency responsible for scheduling and implementing agency requirements, policies, and practices leading to regulatory guidance endorsement. The LMP will remain available throughout FY 2019 to support NRC through technical consultation, analysis, and completion of remaining table-top demonstrations with industry. LMP will also work to update and release other project-support documents and offer them directly to users as supplemental guidance and information (see Subsection 3.4.3).

3.4.2 Guidance Schedule

LMP does not set review and approval schedules for NRC actions. However, the staff has indicated an intent to expedite endorsement in order to make the new process option available for use at the earliest possible opportunity. This, in turn, allows applicants the option of immediately building new and (potentially) more certain licensing strategies for their design.

Table 2 outlines current LMP understanding regarding expected FY 2019 schedule and milestones pertaining to NEI 18-04 endorsement.

Table 2. Key FY-19 Activities.

Date	Item	Activity
Oct 2018	NRC Staff/ACRS Subcommittee on Future Plant Designs meeting	Comprehensive review of the complete LMP licensing-guidance document draft (NEI 18-04) by the ACRS Subcommittee. A staff-composed draft SECY discussing the need for action and a draft authorization guidance document (DG-1353) are also to be reviewed. All three drafts may be updated in response Subcommittee comments.
Dec 2018	NRC Staff/Full ACRS Committee meeting	Updated drafts of NEI 18-04, the staff SECY, and DG-1353 will be reviewed by the full ACRS. A findings letter is expected from the review that may trigger further document updates.
Jan 2019	NEI 18-04, Rev. 0	The draft guidance document will be updated and transmitted from NEI to NRC as complete (non-draft) Revision 0. This represents the LMP final guidance document. NEI will request formal endorsement of the document from NRC.
Feb 2019	NRC Public Comment Period	NRC initiates agency administrative processes appropriate to enabling adoption of NEI 18-04 as regulatory guidance. Notice will appear in the Federal Register and a 30-day public-comment period will likely be required. The staff SECY will be finalized to inform the Commission about what is being

Table 2. (continued).

Date	Item	Activity
		done, to describe the value of the proposed action, and to identify potential policy concerns meriting Commission consideration.
Mar-Apr 2019	Resolution of Public Comments	NRC staff, with technical support from the LMP-NEI-INL team, will resolve stakeholder feedback; NEI 18-04 and/or DG-1353 may require amendment.
Sep 2019	Guidance Document Endorsement	DG-1353 will be finalized and released as a regulatory guide that formally endorses NEI 18-04 for use in non-LWR licensing. Thereafter, the RIBP guidance would be available for use by applicants.

Table 2 represents an aggressive schedule for a new regulatory guide issuance and presumes only limited document revisions will be required. Additional development of the guidance and process-implementation activities by the LMP are not planned after September 2019.

3.4.3 LMP Closeout

As the formal NRC endorsement of NEI 18-04 moves through the administrative steps outlined in Subsection 3.4.2, the LMP will begin project close out activities. This is expected to consist mainly of: (1) completing industry table-top demonstrations (see discussion in Subsection 3.3.3); (2) finalizing the four LMP white papers as supplemental user references (discussed in Subsection 3.2); (3) review and release certain LMP-generated internal reference documents that technically supported proposal development; and (4) development of a project close-out report. Items (3) and (4) are discussed in the following subsections.

The first three documents discussed in the following subsections were written by the LMP team and are currently marked "for internal use only". These documents are currently available only to the LMP team for use as reference material. Upon further review, the LMP may determine these documents can provide applicants with a valuable source of supplemental information on the LMP process. If determinations are made to release these works, they will be edited, subjected to Southern Company management review, and released without reviews by industry or NRC staff.

The fourth document, i.e., the project closeout report, remains to be written and will be developed by LMP late in FY 2019 and submitted to DOE.

3.4.3.1 Analytical Tools Survey

Analytical tools (ATs) appropriate for use in safety assessments are an essential component in all nuclear technology-licensing actions. Activities that support AT creation and use (e.g., development, verification, and validation) must be completed before or coincident with the evolution of a plant safety basis. In 2017, the LMP conducted a survey to identify and assess the current state-of-the-art in ATs able to support non-LWR RIPB decisions.

The LMP surveyed AT for three technology categories: gas-cooled reactors, liquid-metal reactors, and molten-salt reactors. Survey goals were to identify informational gaps according to:

- Ability to predict plant responses to initiating events and to characterize associated uncertainties
- Progression of event sequences that lead to release of radioactive materials

- Performance of mechanistic source term calculations for event sequences that lead to release of radioactive material
- Calculation of dose to the public at necessary locations using the source term information.

Survey results indicated appropriate mechanistic source term assessment capabilities are a significant crosscutting concern for all reviewed technologies. A dedicated mechanistic source term standards group may be advised to develop formal technical requirements and recommend practices for non-LWR mechanistic source term analysis. Such guidance could be either technology neutral or technology specific; however, the guidance should be endorsed by NRC to provide technology developers certainty when establishing the licensing safety basis.

The survey noted that implementation testing might be advisable once the PRA approach is fully developed. Exercises would demonstrate the basic licensing process using design-specific information. Table-top exercises should encompass all event sequences, including those for which mechanistic source terms lead to significant radionuclide release. Demonstrations like this would be useful when launching the modernized framework and would confirm what information is required to complete the process. It would also be an opportunity for applicants to identify unknowns that remain to be addressed for their individual design.

3.4.3.2 Use of Performance-based Criteria

NRC has employed RIPB methods since the promulgation of 10 CFR Part 50.65 (i.e., the Maintenance Rule). Use of performance-based criteria intensified during the late 1990s as a component of the Strategic Assessment and Re-baselining Project. Those activities yielded two results that proved instrumental in establishing RIPB guidance. The first was a Commission-issued "White Paper on Risk-Informed, Performance-Based Regulation," [18]. This paper enabled NRC staff and others to define a set of common terminology. The second was NRC staff development of the reactor oversight process. This process demonstrated the applied value of hierarchical representations of performance objectives. Together, these efforts comprised the bases for guidance contained in NUREG/BR-0303, "Guidance for Performance-Based Regulation," [19] which was part of a subsequent NRC rulemaking process.

The LMP compiled a resource that examined how NUREG/BR-0303 guidance could be applied to non-LWRs. This work supported development of criteria used in advanced reactor design, licensing, and operations. More specifically, the effort sought to answer questions of (1) why use PB approaches; (2) what is the basis for guidance on PB approaches; and (3) how is guidance on the use of PB approaches to be implemented?

Examination of implementing performance-based principles done under this work established that they were well founded and presented a sound basis for LMP white paper development. The insights documented in the LMP report built extensively on work done in the early 2000s and assimilated supplemental accomplishments over the ensuing period. Collected information was used to construct a technical base, to recommended steps for implementation, and to provide a means to exploit generic applicability in principles, policies, and practices rooted in current regulation and adapted for use in non-LWR licensing.

3.4.3.3 Non-LWR Licensing Precedents

Many companies have attempted to license non-LWR plants within the U.S. These efforts (both successful and unsuccessful) date back to the 1980s. These predecessor initiatives generally strived to interpret LWR regulatory requirements in ways that allowed those requirements to be applied to a specific proprietary design. Collectively, these efforts, along with accompanying NRC staff recommendations and Commission policies and decisions, offer a significant body of precedents that are foundational for a new licensing framework.

Hundreds of documents are publically available that offer examples and models in new reactor licensing. The LMP systematically reviewed these legacy works and produced a compendium of more than 200 documents relevant and potentially useful to the LMP work scope. A summary of this collection (along with digital links to their originating source) was employed by the LMP team as a facilitative tool for identifying previous work and approaches and for communicating lessons learned.

While numerous documents dealing with RIPB issues do exist in the public domain, the LMP precedent analysis provides a convenient starting point for retrospective examinations of regulatory expectations and approaches dealing with RIPB design and use. No other single resource is available that includes all relevant work on this topic; industry associations such as NEI, American Nuclear Society, American Society of Mechanical Engineers, Electric Power Research Institute, and individual advanced reactor applicants have all developed approaches on various aspects of RIPB, but these were typically tailored to a specific need or use. The LMP mined these information sources and melded applicable precedents to create the reasoned historical consensus that underlies LMP framework proposals. The LMP believes that the release of this precedent compilation would be a beneficial developmental resource to future applicants.

3.4.3.4 LMP Closeout Report

A LMP project closeout report is planned for release late in FY 2019. The report is expected to highlight key LMP activities, accomplishments, and offer useful team insights and lessons learned on future needs not otherwise discussed the guidance document or LMP white papers. It is anticipated the report will identify and prioritize major outstanding issues and concerns pertaining to process implementation, as well as communicate summary results from table-top demonstration exercises.

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