U.S. Nuclear Regulatory Commission Long-Term Research:
Fiscal Year 2009 Activities

October 2007

Final Report

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Executive Summary

This report represents the first in an annually released series of reports that articulate the U.S. Nuclear Regulatory Commission's (NRC) planned long-term research activities. The NRC currently identifies, as a matter of routine, research activities supporting current and anticipated near-term (within the next few years) regulatory needs. This report documents future technical issues and associated long-term regulatory research activities which are not currently identified within the agency's planning documents. Previous versions of this report were used to inform the fiscal year (FY) 2009 Planning, Budgeting and Performance Management (PBPM) process.

Regulatory research: activities aimed at providing the NRC staff with new methods, tools, and information to support regulatory decisionmaking

Long-term regulatory research: forward-looking regulatory research performed to provide fundamental insights and technical information, or address potential technical issues or identified gaps to support anticipated future (greater than 5 years) NRC needs

Background The NRC performs regulatory research to support the achievement of the goals identified in its Strategic Plan. These goals are to ensure protection of public health and safety and the environment; ensure the secure use and management of radioactive materials; ensure openness in the NRC's regulatory processes; ensure that NRC actions are effective, efficient, realistic, and timely; and ensure excellence in agency management.

The NRC's research strategies are developed to be consistent with the NRC's role as a regulator. For example, the nuclear industry often performs research to establish safety cases (e.g., for license amendments for existing facilities, licenses for new facilities, and new rulemakings). In these cases, the NRC's research enables the independent review of the industry research results and applications, as well as the treatment of potentially significant beyond-design-basis issues. The agency also conducts research to reduce important uncertainties and prepare the agency for the future. Furthermore, the NRC's performance of research helps ensure that the technical bases for regulatory decisionmaking are sound and publicly available to the extent allowable.

The NRC has plans for many of its research activities documented at a variety of programmatic levels. There are plans for specific technical topic areas, programs, and agencywide initiatives. As they exist today, most of these plans focus on current and near-term regulatory issues, with secondary consideration of long-term research activities associated with potentially emerging technical and regulatory issues.

Research-related strategies supporting the NRC's achievement of its goals:

- Ensure that NRC regulations and regulatory processes have sound technical bases;
- Prepare the agency for anticipated changes in the nuclear industry that could have safety, security, or environmental implications;
- Develop improved methods by which the agency can carry out its regulatory responsibilities; and
- Develop and maintain an infrastructure of expertise, facilities, analytical capabilities, and data to support regulatory decision-making.

To support the development of a forward-looking regulatory research program, the NRC has developed a long-term research plan for FY 2009 activities. This report documents the results of the first year's efforts in this regard. It provides the purpose of the plan, identifies long-term research activities to be initiated in FY 2009, provides the basis for the assessed needs, and identifies research areas where the NRC's resources can be leveraged through cooperation with other organizations. The research

plan presents this information at a level of detail suitable to support operational decisionmaking. It relies upon topic-, program- and initiative-specific research plans (either existing or needing development) to provide detailed information on research issues and activities.

This long-term plan will be maintained as a living document. Annual updates will be performed to reflect changes in the agency's knowledge base and priorities, and in the external environment.

Purpose of Plan

The primary purpose of the plan is to identify scoping and/or feasibility studies that will be used to establish the need for (if any), and priority of, long-term research activities. The output of these studies will support the decision to include or exclude subsequent research activities from the NRC's PBPM process. The plan also supports the development of reports and other communication tools (e.g., brochures, information sheets) addressing specific issues (e.g., the NRC's research plans for supporting the licensing and regulation of new facilities).

Long-Term Research Activities

Table E.1 lists long-term research activities to be initiated in FY 2009. These activities support the Global Nuclear Energy Partnership (GNEP), reactor license renewal beyond 60 years, an evaluation of test facility infrastructure for performing integral effects testing for advanced non-light water reactors, and cross-cutting work supporting multiple NRC programs.

Types of long-term research activities:

1) Research supporting major anticipated programs;
2) Research supporting the planning of potential new large test facilities; and
3) Cross-cutting research to:
   a) address new safety technologies and trends affecting multiple NRC programs; and
   b) develop state-of-the-art tools that take advantage of advances in analytical methods and supporting computational infrastructure.

The regulatory research associated with GNEP, a U.S. Department of Energy (DOE) initiative, involves the development of the regulatory infrastructure and the technical bases (e.g., methods, tools, data) needed to support rulemaking, design certification, and regulatory guidance. The types of activities undertaken will be heavily influenced by the technologies selected by DOE (e.g., aqueous separation, liquid metal fast reactor).

The staff expects the regulatory process for evaluating applications for license renewal beyond 60 years to be the same as the current license renewal process. However, research may be necessary to provide additional information to aid the staff's license renewal review of structures and components for plant life extension beyond 60 years and reasonable assurance of safe plant operation during the renewal period. It is anticipated that research will build on the existing experience and knowledge gained during current license renewal reviews and be informed by current research activities (e.g., proactive materials degradation management).

Test facilities are an important source for data needed to support both direct evaluations of proposed systems and design concepts, as well as the validation of models supporting safety cases. The development, operation, and maintenance of such facilities can be costly, and the NRC participates in a number of cooperative programs to leverage its resources. For advanced non-light water reactors, improved integral test facilities or programs at existing facilities may be needed to support regulatory decisionmaking. FY 2009 activities will focus on identifying and

prioritizing research needs. Additionally, FY 2009 resources will be utilized to enter into cooperative testing programs, in cases where these programs address a known, high-priority regulatory need.

Cross-cutting regulatory research (i.e., research that addresses technical issues common to multiple regulatory programs and initiatives) is an important component of the NRC's research portfolio. The long-term cross-cutting research activities identified in this report address potential new safety technologies (e.g., monitoring capabilities using advanced sensors) and the potential for improved analytical tools (e.g., for performing Level 2 and Level 3 probabilistic risk assessment - PRA) enabled by advances in computer hardware and software. In many cases, the planned FY 2009 activities involve the performance of scoping studies to assess the current state-of-the-art, identify specific NRC needs, and develop recommendations for further work.

Table E.1: Long-Term Research Areas and Activities

GNEP
Reactor License Renewal Beyond 60 Years
Test Facilities Integral Effects Test Facilities for Advanced Non-Light Water Reactors
Cross-Cutting Research - Multiphase Computational Fluid Dynamics - Advanced Modeling Techniques for Level 2/3 PRA - Advance Fabrication Techniques - Extended In Situ and Real-Time Inspection & Monitoring Capabilities - Offsite Mitigation Strategies

Work on the activities identified in this report is planned for initiation in FY 2009 to ensure that the agency has an independent technical basis to effectively address future safety and security issues that are anticipated to arise as the agency continues to strive for more realistic assessments and more efficient regulatory decisionmaking. Out-year funding for these activities will be handled via the NRC's normal budget process.

Table E.1 has been developed through a variety of means. These means include the solicitation of research ideas from the staff, the review of existing research plans from both the NRC and external organizations, and the review of selected reports on NRC research activities (including the NUREG-1635 reports produced by the Advisory Committee on Reactor Safeguards - ACRS and NUREG-1802, an expert panel report on the role and direction of NRC's nuclear regulatory research). In addition, input has been provided from the NRC's internal advisory committees and various external stakeholders, such as other government organizations, national laboratories, and industry.

The output from all suggested research activities will be aligned with anticipated regulatory uses. In some cases, consideration has been given to the potential for staff development associated with the planned research. This consideration acknowledges that, in addition to developing/strengthening technical expertise needed to address specific problems (e.g., knowledge regarding the limitations of current methods and tools in particular applications), active participation in a research project can be helpful in developing broader problem-solving skills related to technical issues. These benefits are of increasing importance to the agency as it loses expertise because of staff turnover.

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1 Introduction

1.1 Background

The U.S. Nuclear Regulatory Commission (NRC) performs regulatory research to support the achievement of the goals identified in its Strategic Plan. These goals are to ensure protection of public health and safety and the environment; ensure the secure use and management of radioactive materials; ensure openness in the NRC's regulatory processes; ensure that NRC actions are effective, efficient, realistic, and timely; and ensure excellence in agency management.

Regulatory research: activities aimed at providing the NRC staff with new methods, tools, and information to support regulatory decisionmaking

Long-term regulatory research: forward-looking regulatory research performed to provide fundamental insights and technical information, or address potential technical issues or identified gaps to support anticipated future (greater than 5 years) NRC needs

The NRC's research strategies are developed to be consistent with the NRC's role as a regulator. For example, the nuclear industry often performs research to establish safety cases (e.g., for license amendments for existing facilities, licenses for new facilities, and new rulemakings). In these cases, the NRC's research enables the independent review of the industry research results and applications, as well as the treatment of potentially significant beyond-design-basis issues. Furthermore, the NRC's performance of research helps ensure that the technical bases for regulatory decisionmaking are sound and publicly available to the extent allowable.

The NRC has plans for many of its research activities documented at a variety of programmatic levels. There are plans for specific technical topic areas, programs, and agencywide initiatives. As they exist today, most of these plans focus on current and near-term regulatory issues, with secondary consideration of long-term research activities associated with potentially emerging technical and regulatory issues.

Research-related strategies supporting the NRC's achievement of its goals:

- Ensure that NRC regulations and regulatory processes have sound technical bases
- Prepare the agency for anticipated changes in the nuclear industry that could have safety, security, or environmental implications
- Develop improved methods by which the agency can carry out its regulatory responsibilities
- Develop and maintain an infrastructure of expertise, facilities, analytical capabilities, and data to support regulatory decisionmaking

To support the development of a forward-looking regulatory research program, the NRC has developed a long-term research plan. This plan identifies long-term research activities; provides the basis for the assessed needs; and identifies research areas where the NRC's resources can be leveraged through cooperation with other organizations. The research plan presents this information at a level of detail suitable to support operational decisionmaking. It relies upon topic-, program- and initiative-specific research plans (either existing or needing development) to provide detailed information on research issues and activities.

As further discussed in Section 1.3, the specific activities covered by the plan involve either scoping studies designed to identify the further exploration required for the topic areas identified or the development of technical infrastructure to support anticipated future regulatory needs.

The long-term research plan will be maintained as a living document, with this report being the first in a series of annual updates. These updates will be performed to reflect changes in the agency's knowledge base and priorities, and in the external environment. These updates will address, in addition to the startup of new research activities, the termination or redirection of ongoing activities to better meet the needs of the agency.

This report provides the purpose of the plan and identifies long-term research activities to be initiated in fiscal year (FY) 2009.

1.2 Objectives

The primary purpose of the plan is to identify scoping and/or feasibility studies that will be used to establish the need for (if any), and priority of, long-term research activities. The plan will also support the development of reports and other communication tools (e.g., brochures, information sheets) addressing specific issues (e.g., the NRC's research plans for supporting the licensing and regulation of new facilities). The intent is that the NRC's plans for future research will be both more cohesive and transparent to both internal and external stakeholders as a result of this process.

The specific objectives of the plan are to:

1 Identify long-term research activities which need to be scoped (starting in FY 2009 in the case of this report);
2 Inform out-year budget planning activities, starting with the FY 2009 budget; and
3 Facilitate the identification of long-term activities where NRC research can be leveraged by entering into (or extending) collaborative agreements with external entities.

1.3 Report Role and Scope

The NRC is conducting regulatory research activities that address the current, varied needs of its different regulatory programs. The plans for these activities are formally documented through a variety of means, including the operating plans for the performing offices, contracts and grants, and topic-specific research plans.

This long-term research planning report addresses activities not covered by existing regulatory research programs. For example, the NRC's planned research activities in the area of advanced reactors (notably high-temperature gas-cooled reactors) are documented in the Advanced Reactor Research Plan (ARRP)[1]. Therefore, the long-term research planning effort addresses only the aspects of that topic that are not already covered in the ARRP. On the other hand, the NRC currently does not have any plans to address the broad topic of advanced sensors[2]. Therefore, the long-term research planning effort has considered the potential need for research activities in this area.

[1] Available in the Agencywide Documents Access and Management System - ADAMS (accession number ML070600065)
[2] The ARRP does include a limited number of sensor-related activities aimed at advanced reactors.

The long-term research planning effort is further constrained to the consideration of either scoping studies or limited technical infrastructure development activities. The scoping studies are aimed at determining what topic areas need further work, what work should be done, when the work should be done, and who (e.g., the NRC or industry or both) should do the work. The infrastructure development activities are aimed at developing methods, models, tools, and/or data that will support anticipated future regulatory needs. In either case, it is expected that should substantial follow-on research efforts be required, proposals for such activities will be developed outside of the long-term research planning effort and will be considered as part of the normal NRC budgeting process.

1.4 General Assumptions

There are several general assumptions pertaining to the agency's role in future research, collaboration and coordination with external stakeholders and the development of broad, internal capabilities that have been used to guide the selection of the research activities summarized in this report.

With respect to the agency's fundamental research role, it is assumed that research will remain focused on contributing to the technical basis development necessary for supporting known or anticipated regulatory decisionmaking. Licensees and applicants will continue to perform the developmental research activities used to justify requested regulatory decisions while the agency-sponsored research activities will largely remain confirmatory in nature. This separation will allow the agency to independently evaluate the supplied technical justification.

However, coordination with industry owners and research groups, licensees, and applicants will still be important in many cases to ensure that principal technical issues are appropriately identified and addressed. Additionally, it is assumed that future NRC research will continue to rely on extensive collaboration and coordination with other external organizations. These organizations include universities, government and independent laboratories, other government agencies, and international organizations and governments. This interaction allows the NRC to leverage its resources by assimilating relevant lessons learned, operating experience, and research findings from other organizations to most efficiently reveal areas that may require research.

Finally, it is assumed that the agency will continue to support personnel and infrastructure development so that capabilities will remain in place to support agency-sponsored research. Specifically, it is assumed that the agency will develop, maintain, or enhance, as appropriate, the following capabilities:

- Broad expertise in critical technical areas to support multipurpose regulatory activities, maintenance of in-house expertise, and knowledge management,
- Knowledge management tools applicable to nuclear technology for both retaining and transferring knowledge,
- Smart tools and technology to decrease staff training requirements, and allow more efficient, focused regulatory decisionmaking, and
- Computing and information technology (IT) infrastructure to manage increased amounts of available information, provide smart/targeted access to needed information, increase information portability, and increase availability and use of sophisticated, networked simulation tools.

These capabilities will be necessary for the agency to most efficiently handle and process information, promote knowledge management, and effectively focus resources.

1.5 Process for Identification of Research Activities

The long-term research activities identified in this report were developed through a variety of means. These means include the solicitation of research ideas from the staff (principally staff in the Office of Nuclear Regulatory Research – RES, but also staff and management representatives from each of the program offices), the review of existing topic-specific and program-specific research plans from both NRC and external organizations, the review of selected reports on NRC research activities (including the NUREG-1635 reports produced by the Advisory Committee on Reactor Safeguards – ACRS – and NUREG-1802, an expert panel report on the role and direction of NRC's nuclear regulatory research) and other relevant currently-existing planning tools (e.g., the RES Operating Plan). A draft version of this report was provided to external stakeholders, and comments were received from other government organizations, industry groups, and several of the national laboratories[3]. In addition, input was received in the form of briefings and formal letters from the ACRS and the Advisory Committee on Nuclear Waste and Materials (ACNW&M)[4].

During the development of this report, supporting information was developed in each of the following topic areas:

- Materials
- Structural and Component Integrity
- Non-destructive Examination
- External Hazards
- Nuclear Fuels
- Thermal-Hydraulics
- Severe Accidents and Consequences
- Radiation Protection
- Environmental Assessment and Protection
- Reprocessing Spent Nuclear Fuel
- I&C and Electrical Systems
- Human Factors
- Fire Safety
- Risk Assessment
- Nuclear Material / Plant Security
- Emergency Planning & Incident Response
- Decision Support

1.6 Report Organization

Chapter 2 provides a description of activities within several research areas. The Global Nuclear Energy Partnership (GNEP) and Reactor License Renewal Beyond 60 Years are identified as program initiatives that will require research to support licensing decisions. Research activities related to the development of an integral test facility and cross-cutting capabilities are also discussed. It is envisioned that these activities will support a broad array of agency programs and initiatives.

[3] ADAMS accession number ML071970028)
[4] ADAMS accession nos. ML071360105 and ML071790071

2 Program Areas and Initiatives with Supporting Research Needs

2.1 Global Nuclear Energy Partnership

2.1.1 Background

GNEP is a U.S. Department of Energy (DOE) initiative that aims to achieve the following::

- Expand the use of nuclear power,
- Minimize nuclear waste requiring disposal in a geologic repository,
- Develop advanced proliferation resistant recycling and separation technologies,
- Develop advanced reactors for transmutation of transuranics from spent fuel,
- Establish reliable fuel services,
- Demonstrate grid-appropriate, exportable reactors, and
- Enhance nuclear safeguards technology.

Key Messages

- Technologies associated with GNEP are under development by DOE.
- Potential known candidates are advanced aqueous separation or electro-chemical “pyro” processing (for reprocessing) and a liquid metal fast reactor (for "burning").
- NRC is taking steps to develop the regulatory and technical infrastructure needed to license GNEP-related facilities, commensurate with DOE’s progress in identifying GNEP technologies.

To accomplish these goals, DOE hopes to partner with industry to build an industry-led, commercial-scale spent nuclear fuel reprocessing/fuel fabrication facility and a fast burner reactor.

More specifically, DOE has proposed three types of inter-related GNEP facilities:

- a spent nuclear fuel recycling facility, referred to as the Consolidated Fuel Treatment Center[5] (CFTC),
- an advanced fuel cycle research facility, referred to as the Advanced Fuel Cycle Facility (AFCF), and
- an advanced burner reactor[6] (ABR).

DOE presents the GNEP policy and proposed implementation plan for closing the nuclear fuel cycle in its GNEP Strategic Plan[7].

The role of the NRC in licensing the possible GNEP facilities has not yet been determined. However, for the purposes of this report, it is assumed that both the CFTC and the ABR will be licensed and regulated by the NRC. It is expected that both facilities will be built either at a commercial site or an existing DOE site. Furthermore, DOE is considering the co-location of the CFTC and the ABR.

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[5] A commercial reprocessing facility is expected to include capabilities for complex chemical separations of fission products and transuranic nuclides, interim storage of separated radionuclides, waste storage and solidification, and fabrication of fuel containing transuranic nuclides.

[6] The ABR (sometimes referred to as an advanced processing reactor or advanced recycling reactor) will be a nuclear reactor that accepts recycled nuclear fuel and consumes more transuranic elements than it creates, while generating electricity. It is expected to be a liquid metal-cooled fast reactor. In the context of this type of reactor, the term “burn” means to transmute or convert transuranics into shorter-lived isotopes.

[7] U.S. Department of Energy, “Global Nuclear Energy Partnership Strategic Plan”, GNEP-167312, Rev. 0, January 2007.

In addition, the specific technologies that will be developed under GNEP are still being considered by DOE. DOE has established cooperative agreements with four commercial entities and is working with these entities to identify candidate reprocessing and ABR technologies. In the near-term, it appears that DOE plans to pursue advanced aqueous separation (uranium-extraction) or electro-chemical technologies that do not separate plutonium, as well as sodium-cooled fast reactors.

The NRC has already engaged in technical exchanges with DOE to keep abreast of DOE plans and evaluations of technologies to be used for GNEP, and to anticipate any changes to the NRC's regulatory infrastructure that would be needed to license commercial GNEP facilities. These interactions have been formalized via a memorandum of understanding (MOU) between the NRC and DOE, dated July 13th, 2007[8]. This MOU includes the following activities:

- DOE will share the latest information on advanced recycling technologies with the NRC, permitting NRC to provide DOE with insights regarding the licenseability of the technologies.
- The NRC will participate in and observe DOE tests, simulations, and demonstrations.
- The NRC will review and provide feedback to DOE on GNEP reports and engineering studies, review literature and take facility tours.
- The NRC will provide annual reports to DOE on work performed under this MOU.

These activities will be undertaken, as appropriate, based on further developments of the GNEP program.

The staff has evaluated a number of regulatory options for licensing GNEP facilities, including rulemakings that may be necessary in multiple areas (e.g., safeguards, waste management, environmental protection) to address the unique aspects of GNEP technologies. The NRC staff will be performing gap analyses for all NRC regulations to identify changes in regulatory requirements that would be necessary to license a reprocessing facility and advanced recycling reactor. Subsequently, the NRC will develop the technical basis documentation to support rulemaking for Title 10, Part 70, "Domestic Licensing of Spent Nuclear Material," of the *Code of Federal* Regulations (10 CFR Part 70) with revisions to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," as appropriate[9].

The Secretary of Energy's decision on the path forward for GNEP is expected by June 2008. Given the uncertainty in the GNEP schedule and technology selection, the staff does not expect to begin the majority of the work to develop the technical and licensing infrastructure for GNEP until FY 2009. Nevertheless, the NRC staff will continue to conduct its activities under the GNEP MOU to be in a position to inform DOE's June 2008 decision by providing feedback to DOE concerning potential regulatory, safety, safeguards, and security issues.

[8] Available in ADAMS at accession no. ML071210153

[9] Addition information can be found at ADAMS accession nos. ML063240070 (SECY-07-0081) and ML071800084 (SRM-SECY-07-0081).

2.1.2 Regulatory Uses

Research will be needed to support regulatory infrastructure development. Technical bases are required to support the NRC's safety evaluations for pre-application and design certification reviews, as well as for rulemaking. This will require the generation of staff expertise, technical reports and analytical tools that can be used by the program offices to support safety evaluations, as well as to identify any needed updates to regulatory guidance.

Data and information are needed to assess public health, safety, security, and environmental impacts from potential routine and accidental releases of radionuclides from full-scale facilities. Important contributors to risk need to be identified. Specifically, tools and technical knowledge need to be updated or developed in the following areas:

- aqueous and non-aqueous chemical separation processes,
- waste solidification, packaging and transportation processes,
- fabrication and testing of irradiated and non-irradiated transmuted fuels, and
- transmutation of transuranics in liquid metal fast reactors.

In addition, risk-informed strategies are needed to assess credible accidents, criticality scenarios, waste disposition, co-location issues, and any items specific to advanced liquid metal reactor technology. The staff needs to develop the technical expertise and tools to independently review and evaluate the acceptability of a spent fuel reprocessing plant application and an advanced liquid metal reactor design certification, including the safety and environmental impact analyses. Similarly, the staff needs the expertise and tools to deal with waste stream and effluent issues specific to the GNEP technologies employed. The agency needs these capabilities to support the development of regulatory criteria (including quantification of safety margin); independently confirm an applicant's results, data, and computer codes; or develop an understanding of the pertinent risk metrics.

2.1.3 Technical Areas and Activities

In SRM-SECY-07-0081 the Commission expressed its support for long-term research efforts to develop and maintain technical expertise relevant to the types of facilities envisioned for GNEP, commensurate with DOE activities and subject to available funding. As stated above, research activities will focus on reprocessing and fuel fabrication technologies, as well as the use of reprocessed fuel in the ABR. Examples of activities that may be initiated in FY 2009 (depending on further program developments and available resources) include the following:

Planned Schedule:

- Secretary of Energy's Decision – July 2008
- Completion of first-order gap analysis for all NRC regulations with respect to GNEP licensing – December 2008 (contingent on DOE Secretary's Decision and Congressional appropriations)
- Initiation of Part 70 rulemaking, with revisions to Part 50 as necessary - TBD

Deliverables:

- NRC technical basis document to support Part 70 rulemaking with revisions to Part 50 as necessary – December 2009
- GNEP-specific research plan documenting planned research activities – 2009
- Report identifying key experimental data needs and intended plans for obtaining them - 2010

- summarizing the domestic and international knowledge base and operating experience[10]
- developing the expertise, guidelines, and codes for assessing the various GNEP technologies
- developing risk assessment methods, tools, data, and criteria addressing the unique characteristics of the GNEP facilities, their potential co-locations, their waste streams, and their effluents
- considering the adequacy of the current two-tiered waste classification system, and examination of the potential use of 10 CFR 61.58, "Alternative Requirements for Waste Classification and Characteristics"
- modeling and assessing effluent control systems for gaseous and liquid radionuclide releases
- developing fire models that address GNEP fire hazards and protection schemes
- developing risk-informed strategies to evaluate accident assessment capabilities for spent nuclear fuel reprocessing and fabrication facilities and the ABR
- developing model updates for ABR systems analysis (e.g., sodium/water reaction models, update of the Super System Code[11] series)
- developing the tools needed for performance of nuclear analysis for reprocessing activities and reactor analysis
- reviewing the applicability of past experiments related to liquid metal reactors, reprocessing, and waste disposition
- identifying any additional experimental facilities that are needed to support these activities (e.g., a sodium test loop, hot cells, neutron source for materials and fuels testing)

It is worth noting that the activities above are based on the assumption that GNEP licensing would rely on a similar approach to analysis and experimentation as used in past licensing activities. DOE has indicated that it intends to rely on computational models more heavily than traditional applications have, using first principle analyses to replace some or all supporting experiments[12]. If this intention comes to fruition, the NRC will need commensurate activities to develop the standards and criteria for review of these analyses, assuming that the NRC fundamentally agrees that this is an acceptable approach.

The specific long-term research activities related to GNEP will be informed by the

Leveraging Resources

The NRC has already engaged in technical exchanges with DOE on this topic, and will continue to do so as appropriate. In addition, Argonne National Laboratories is facilitating the exchange of information between the major stakeholders. The NRC has worked extensively with entities such as Brookhaven National Laboratories on a number of technical issues related to GNEP (e.g., liquid-metal fast reactors). Meanwhile, Sandia National Labs has ongoing internal research and development associated with severe accident issues for liquid-metal reactors. The NRC will continue to stay abreast of these activities and seek opportunities for further cooperative efforts in this area.

[10] Examples of related activities and facilities that will be considered include the Savannah River mixed-oxide fuel fabrication facility (MFFF), reprocessing activities carried out by foreign partners, the Experimental Breeder Reactor 2, the Fast Flux Test Facility, and the Clinch River Breeder Reactor project.

[11] The Super System Code (SSC) series comprising SSC-L for loop-type LMRs and SSC-P for pool-type LMRs was developed by Brookhaven National Laboratory for the NRC in the late 1970s.

[12] For related information, see *Workshop on Simulation and Modeling for Advanced Nuclear Energy Systems*, August 2006, http://www.sc.doe.gov/ascr/Misc/gnep06-final.pdf.

DOE selection of specific technologies (currently scheduled for June 2008), and its ongoing activities related to research and development. It is envisioned that once the GNEP program has reached the appropriate level of maturity, the NRC will develop a research plan specific to its GNEP activities.

2.2 Reactor License Renewal Beyond 60 Years

2.2.1 Background

Key Messages

- Plant modifications and favorable economic conditions may increase impetus for license renewal.
- Current technical basis for license renewal are the *Generic Aging Lessons Learned* (GALL) and *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS) reports.
- Research Objectives:
  - Support staff's review of structures and components for plant life extension beyond 60 years.
  - Provide reasonable assurance of safe plant operation during the renewal period.

The original operating licenses for commercial nuclear power plants are valid for 40 years from the issuance date. Currently, 48 applications to renew this original license for an additional 20 years have been approved and renewal applications for 14 plants are under review. Additionally, potential applicants have submitted letters of intent indicating that 24 additional reactors will apply for license renewal between 2007–2013.

Many plants have made significant plant modifications and upgrades to support license renewal. For example, many plants have replaced steam generators, to support continued operation, including the potential for long-term extended life. These modifications and upgrades, in many cases, are designed more robustly and perform more efficiently than the original plant equipment. It is expected that plants will attempt to maximize the return on these investments. Additionally, the revision of 10 CFR 50.61, "Fracture Toughness Requirements for Protection against Pressurized Thermal Shock Events" (the pressurized thermal shock - PTS screening rule), may reduce or eliminate a potential life-limiting regulatory consideration for several plants.

Given these considerations, life extension may prove to be a cost-effective way to add new power generation at a fraction of the cost of building new plants. Therefore, it is possible that some current licensees will apply for an additional 20 year plant life renewal beyond their current (or anticipated) 60-year license. Both the Electric Power Research Institute (EPRI) and DOE[13] have suggested that life extension is likely to be pursued by a number of existing plants and its feasibility should be considered by both industry and NRC. While several industry representatives have informally inquired about the possibility of license renewal beyond 60 years, no formal letter of intent to pursue such a renewal has been received.

The earliest that a plant can seek a license renewal request under 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," is 20 years before the termination of its existing license. The earliest date for an expiring extended license is 2029 (Dresden 2 and Ginna). Therefore, 2009 is the earliest that a request could be received. However, plants have typically submitted their renewal applications 10 – 15 years before their license termination date so that, once the NRC has rendered the final decision on the request, there is sufficient time to either complete necessary applications to satisfy other Federal, State, and local requirements, or plan for decommissioning.

[13] ADAMS Accession Nos. ML071900353 and ML071930343, respectively

Considering this schedule and the anticipated near-term focus on evaluating license renewal requests up to 60 years of operation, 2014 – 2019 is a reasonable timeframe for expecting the first requests for license renewals beyond 60 years of operation. Any pre-application topical reports would be submitted for review 1–2 years before the license renewal applications.

2.2.2 Regulatory Uses

The safety issues for current license renewal applications are regulated by 10 CFR Part 54 while environmental issues are regulated by 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.” There is no regulatory limit in either regulation which specifically precludes additional life renewal beyond 60 years as long as the regulatory requirements in 10 CFR Parts 51 and 54 and all other licensing conditions are met. The applicant is required to address the technical aspects of plant aging and describe how those effects will be managed. The applicant must also evaluate the potential impact on the environment from an additional 20 years of operation.

For the safety review, the principal technical bases for evaluating applications for plant license renewal beyond 40 years include the following:

- “Generic Aging Lessons Learned (GALL) Report” (NUREG-1801)
- “Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants” (NUREG-1800)
- Regulatory Guide 1.188, “Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses”

For the environmental review, the principle bases for evaluation are the following:

- "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (GEIS) report (NUREG-1437)
- “Standard Review Plans for Environmental Reviews for Nuclear Power Plants” (NUREG-1555, Supplement 1)
- Regulatory Guide 4.2, “Preparation of Environmental Reports for Nuclear Power Stations”

The GALL report documents the basis for determining when existing programs are adequate and when existing programs should be augmented for license renewal. This report is the basis for identifying those programs that warrant particular attention during the NRC's review of a license renewal application. The GEIS report assesses the scope and impact of environmental effects that would be associated with license renewal at any nuclear power plant site such as endangered species, impacts of cooling water systems on fish and shellfish, and ground water quality. A plant-specific supplement to the GEIS is required for each application for license renewal.

The regulatory process for evaluating applications for license renewal beyond 60 years is expected to be the same as the current license renewal process. However, research may be necessary to provide:

a) additional information to aid the staff's license renewal review of structures and components for plant life extension beyond 60 years, and
b) reasonable assurance of safe plant operation during the renewal period.

It is anticipated that research will build on the existing experience and knowledge gained during current license renewal reviews and be informed by current research activities (e.g., proactive materials degradation management). As appropriate, any additional research will be used to make corresponding changes to the Standard Review Plans and regulatory guides associated with both license renewal and plant operation. For instance, it may be necessary to incorporate plant safety insights within the regulatory framework in other technical areas (e.g., seismic, I&C) that have matured since the last license extension.

2.2.3 Technical Areas and Activities

There are several technical areas that need to be considered by the staff to evaluate license renewal applications and to have assurance that the plants will operate safely during the license renewal timeframe. Many of the technical areas currently evaluated during license renewal are expected to be applicable for subsequent life extensions. Specifically, issues related to aging of passive system components and electrical and instrumentation systems are a concern. Also, it will be necessary to have assurance that long-term environmental and health requirements are met. It is recognized, however, that additional issues may need to be considered to evaluate continued plant operation, especially since many of the plants will have been operating for 10 to 30 years at power levels higher than originally licensed.

Planned Schedule
FY 2008:
- Outreach to nuclear industry to identify key technical and regulatory issues
- Conduct joint NRC/DOE workshop – February
- Conduct RIC session – March

FY 2009:
- Identify possible supporting extended in situ and real time instrumentation and monitoring techniques.
- Conduct scoping study to assess and prioritize technical and regulatory issues.
- Develop research plan

Deliverables
- Scoping study identifying technical and regulatory issues – June 2009
- Preliminary Research Plan – September 2009

Aging-related effects to structures, systems, and components will need to be independently evaluated by the NRC to support license renewal requests. For instance, critical passive system components should be assessed to ensure that sufficient safety margins remain when accounting for continued material degradation. Some components and locations with existing and likely future degradation concerns include welds, building structures, equipment supports, anchorages, buried pipes and tanks, reactor vessel internals, nozzles and penetrations, dry well liner walls, and steam generator tubes. While many locations having materials susceptible to active degradation mechanisms are evident from current operational experience, it is possible that operation beyond 60 years could result in other combinations of materials, degradation mechanisms, and locations that should be considered. It will therefore be important to maintain and expand existing operating experience databases so that the safety implications associated with plant aging can be assessed.

Aging of electrical and instrumentation systems will also need to be evaluated. Continued degradation of insulation and connections is expected. Examples of specific possible research activities in this area include the following:

- study the rate of failure of instrumentation and control cables and evaluate the service life beyond 60 years,
- identify a zone of influence and a range of factors where component failures or electrical transients could cause a nuclear plant trip,
- determine how breaker failure rate changes with time from 60 up to 80 years, and.
- correlate the failure rate with cycles of operation, operating environment and age (480V, 5kV, 8 kV, 10 kV and 15kV).

It is possible that structural component, electrical system, and instrumentation aging will be monitored more closely and accurately as a result of improvements in inspection and real-time monitoring. Hence, enhanced aging management programs may be employed to mitigate issues related to plant aging. Some research may therefore be necessary to understand the effectiveness of these new strategies so that safety improvements can be appropriately credited.

Also, the safety impacts resulting from using new and/or advanced components to either upgrade or replace obsolete equipment should be evaluated. For example, research may be needed to assess the safety implications associated with the operational interfaces between existing power plants and new digital I&C systems that may be added to support life extension. Evaluation of environmental issues may also require research in environmental modeling and radiation protection.

Finally, advanced PRA may also provide a valuable tool for quantifying the overall risks associated with life extension by considering historical operational experience with the effects of future plant aging, inspection and mitigation programs, component/system upgrades, environmental modeling, and radiation protection. Such an analysis could help identify the most risk-significant issues for plant operation during the renewal period.

While the discussion above identifies some technical areas to be considered, specific research needs will be identified by: (a) evaluating principal technical limitations to extended plant operation, (b) ensuring that a sufficient understanding of related aging and environmental issues has been or can be developed; and (c) implementing, as applicable, more realistic, yet adequately conservative, models to support extended life evaluation. Through this study, methodologies and degradation acceptance criteria can be developed to provide guidance to the NRC staff for making a timely assessment of the risk-associated degraded conditions identified at specific plants.

Leveraging Opportunities

- DOE is working with the NRC to identify long-term research activities.
- EPRI has initiated discussions with DOE and NRC on this issue.
- EPRI has expressed interest in technical collaboration.

A scoping study will be initiated in FY 2009 to identify principal technical issues and develop research plans to assess any important knowledge gaps associated with extending the existing technical basis. Planned research on advanced instrumentation and monitoring techniques beginning in FY 2009 (Section 2.4.7) will also be leveraged to determine if possible technologies

exist that could support license renewal. It is anticipated that any research identified to support reactor license extension beyond 60 years should begin several years before the receipt of an application, or pre-application topical report, related to license renewal beyond 60 years in order to support the agency's effectiveness goals.

In the interim, outreach to the nuclear industry is planned to explore possible timelines for license renewal. Also, collaboration with DOE and coordination with the nuclear industry has been initiated and will continue to be pursued to begin to identify key technical and any associated regulatory issues. A joint workshop between DOE and the NRC is being held in February 2008 to begin this dialog. Additionally a session on reactor life extension is planned for the Regulatory Information Conference in March 2008. These interim activities will support and inform the scoping study that will be initiated in FY 2009.

2.3 Test Facilities

2.3.1 Background

Test facilities that provide empirical data on the performance of systems constitute an important part of the technical infrastructure supporting regulatory decisionmaking. Separate effects facilities are utilized for activities such as model development and validation, and integral effects facilities are utilized for activities such as assessing overall system performance. As the industry and the NRC make increasing use of sophisticated computer-based modeling, it becomes increasingly important that the agency obtain empirical data needed to ensure that the models are solidly grounded in reality, and that the uncertainties in the model predictions are adequately understood. The development, operation, and maintenance of test facilities can require considerable resources. To leverage its resources, the agency continues to enter into cooperative agreements with domestic and international partners.

2.3.2 Regulatory Uses

The activity discussed in the following section is intended to support the development of technical information for a range of regulatory decisions related to advanced non-light water reactors (non-LWRs). This information will support the NRC's efforts to develop staff expertise, independently assess applicant submittals and develop the technical bases needed to establish regulatory requirements and guidance.

2.3.3 Integral Effects Test Facilities for Advanced Non-Light Water Reactors

The NRC has the responsibility to ensure the adequacy of the safety criteria that are used for licensing advanced non-LWRs (e.g., very-high-temperature gas reactors, fast sodium-cooled reactors) as well as confirming the adequacy of the analytical tools used to demonstrate that the safety criteria are met. Early LWR licensing experience shows that independent safety research by the NRC at separate effects facilities or large integral effects test facilities is

Leveraging Opportunities:

Developments in this area will be coordinated with DOE, given their extensive efforts to develop such facilities in the past and their access to a number of relevant facilities. In addition, related international efforts will also be reviewed. For more information on international experience and research needs with advanced reactor testing, see the Organization for Economic Cooperation and Development report, *Support Facilities for Existing and Advanced Reactors (SFEAR) [*Nuclear Safety Series, NEA/CSNI/R(2007)6].

needed to provide the data to achieve an adequate technical basis to support licensing decisions (e.g., testing required to establish the safety criteria for reactivity accidents and loss of coolant accidents).

For non-LWR licensing, it should be anticipated that safety testing at separate effects facilities and integral test facilities will also be used to evaluate safety issues related to the adequacy of the proposed criteria and analytical methods. Test facilities may be needed to establish and verify regulatory limits on the fuel, graphite, metallic and composite components as well as integral test facilities to resolve analytical code modeling issues associated with specific postulated accidents for the advanced non-LWR designs. These might involve graphite oxidation models for air-ingress events for high-temperature gas reactors, sodium–water reaction models for fast sodium-cooled reactors, and fission product transport models for both reactor technologies. Specific issues that may warrant examination should be based on risk impacts and uncertainty and should be identified as part of the pre-licensing reviews of advanced non-LWRs.

Schedule / Deliverables:

- A white paper, or update to the Advanced Reactor Research Plan, that identifies high-priority experimental needs. – July 2009
- Cooperative agreements, as appropriate, to address these knowledge gaps.

This activity is closely related to the agency's efforts to support GNEP (discussed previously in this report), as well as other advanced reactor initiatives (most notably the Next Generation Nuclear Plant – NGNP project). In addition, the agency has developed a draft Advanced Reactor Research Plan, as identified in Section 1.3. The activity identified here is intended to fill in experimental testing gaps as they are identified. FY 2009 activities will focus on scoping and initially prioritizing research needs. These needs will likely span a wide range of different technical areas, as discussed above. FY 2009 resources will also be utilized to enter into cooperative testing programs, in cases where these programs address a known, high-priority regulatory need.

2.4 Cross-Cutting Research

2.4.1 Background

Cross-cutting regulatory research (i.e., research that addresses technical issues common to multiple regulatory programs and initiatives) is an important component of the NRC's research portfolio. By its nature, cross-cutting research can provide a broad technical base supporting the agency's decisionmaking. For

Example Long-Term Benefits of Cross-cutting Research:

- Reactor Safety Study (1975) - PRA methods, data, and insights developed for this 3-year landmark study (documented in WASH-1400), enabled the development of the NRC's 1995 PRA Policy Statement and numerous subsequent risk-informed initiatives regarding the licensing, regulation, and oversight of commercial nuclear power plants.
- Materials research - Experimental and analytical work related to heavy-section steel reactor pressure vessels conducted in the 1970s - 1990s enabled the initiation of a multidisciplinary project in 1999 to develop the technical basis to support an ongoing risk-informed revision of the pressurized thermal shock rule (10 CFR 50.61).
- Severe accident research - NRC activities in the 1980s and 1990s led to more realistic conclusions regarding the likelihood of early containment failure due to certain phenomena (e.g., steam explosions, direct containment heating). Severe accident research has also served as the technical basis for developing an alternate source term for design-basis offsite dose analysis, which led to both cost-savings and greater regulatory effectiveness.

example, as shown by past cases (in the text box above), cross-cutting research can, in addition to answering the immediate problem posed to the staff, enable the development and execution of broader NRC initiatives.

The NRC's current cross-cutting research activities include experimental and analytical investigations of key phenomena; the development of improved analytical methods and models, software tools, and data; and the performance of integrated systems analyses. These activities are identified using input from a variety of sources (including Commission directives, program office user need letters, recommendations from technical advisory groups, lessons from operating experience and inspection findings, research results, and recommendations from oversight committees and peer review panels) and are assigned resources following an agencywide prioritization process which considers the potential impact of the research on the achievement of the NRC's strategic goals.

Many of the NRC's current cross-cutting research activities are quite useful in either addressing the agency's long-term needs or in providing a foundation for future work to address these needs. However, these activities were generally not identified, scoped, or prioritized with long-term applications in mind.

2.4.2 Regulatory Uses

In general, the cross-cutting research activities discussed in the following sections are aimed at preparing the agency for future decisionmaking regarding the licensing, regulation, and oversight of facilities. In particular cases identified below, the research will address specific regulatory needs. All of the research products (e.g., methods, tools, data, guidance documents, technical results and insights) will be developed to address the needs of staff users.

In a number of cases, it is expected that the research activities will have potentially significant staff development benefits. Active participation in a research project can be helpful in developing broader problem-solving skills related to technical issues, as well as in developing and strengthening technical expertise needed to address specific problems (e.g., knowledge regarding the limitations of current methods and tools in particular applications). These benefits are of increasing importance to the agency as it loses expertise as the result of staff retirements.

2.4.3 Long-Term Research Activities

This section describes specific long-term, cross-cutting research activities identified using the process described in Chapter 1. In general, these cross-cutting activities do the following:

- address issues associated with anticipated or proposed new safety technologies (e.g., nanotechnology) that may impact a number of NRC programs
- enable the agency to develop state-of-the-art tools that take advantage of ongoing or anticipated developments in analysis technologies (e.g., simulation methods) and supporting infrastructure (e.g., computers and software)

In some topic areas, the technical issues underlying the research are well understood and the research activities are well defined. In other areas, the issues are less well defined, and scoping studies will be performed to inform the direction of future research activities in the area.

2.4.4 Multiphase Computational Fluid Dynamics

Computational fluid dynamics (CFD) is used widely in a number of fields, including chemical processes, environmental transport, and power generation. CFD provides detailed three-dimensional predictions of temperature, velocity, and chemical species distributions in a fluid and is already used by the agency to study safety-related problems for *single-phase* flow. Currently, the system analysis tools used by the agency (e.g., TRACE[14]) do not account for most three-dimensional and/or developing aspects of multiphase flows in the reactor system, and there is no agency *multiphase* CFD capability to address these shortcomings. These issues could be addressed with CFD, provided that models and capabilities are developed for two-phase flow in a boiling/condensing system. In addition, there is increasing interest in multiphase CFD among the nuclear industry and international regulators, and the staff expects to receive safety analyses in the future which rely on multiphase CFD (e.g., rod bundle departure from nucleate boiling analysis, advanced plant heat exchanger performance, high-temperature gas reactor analysis).

Leveraging Opportunities:

A number of other entities are exploring the use of CFD for multi-phase, nuclear-specific purposes. These entities include, but are not limited to:

- Le Commissariat à l'Énergie Atomique (CEA), Électricité de France (EdF), Areva NP and l'Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
- The Center for Nuclear Waste Regulatory Analyses
- EPRI
- The Committee on the Safety of Nuclear Installations

To address these issues, work in FY 2009 will focus on implementation of a program that will do the following:

- stay abreast of domestic and international initiatives related to the use of multiphase CFD (e.g., the French NEPTUNE[15] project)
- build upon the state-of-the art summary of CFD methods for two-phase flow generated by a recent Committee on the Safety of Nuclear Installations (CSNI) working group
- examine the various research and commercial codes available and evaluate their strengths and limitations for performing multiphase CFD analyses
- perform benchmark calculations against simple but well-characterized data and participate in international benchmarking efforts as appropriate

Deliverable:

A white paper that codifies the activities cited above, and recommends out-year activities that are needed to support development of a multiphase CFD analysis capability.

[14] The TRAC/RELAP Advanced Computational Engine (TRACE) is a thermal-hydraulic systems analysis tool used by the agency.

[15] NEPTUNE is a multi-scale thermal-hydraulics code being developed jointly by CEA, EdF, Areva NP, and IRSN (*NEPTUNE* is not an acronym).

The overall objective of the program is the development of a multiphase CFD analysis capability suitable for a range of safety-significant applications.

2.4.5 Advanced Modeling Techniques for Level 2/3 PRA

Level 2 PRA requires the treatment of complex severe accident phenomenology within a probabilistic framework. The current approach employs accident progression event trees (APETs) or containment event trees (CETs). With general advances in computers, improved approaches that can take advantage of integrated severe accident models are becoming increasingly feasible.

Model improvements have been incorporated into the agency's severe accident computer code (MELCOR) based on the following:

- a better understanding of severe accident progression (extent and timing of core damage and radiological release)
- an increased emphasis on integral best-estimate analysis

While these detailed phenomenological models have substantially improved the agency's capability to assess plant response for selected accident scenarios, the detailed best-estimate predictive capability has not been integrated into all key agency activities. In particular, the current state of Level 2 PRA does not, in an integrated fashion, utilize the phenomenological MELCOR modeling to quantify the likelihood of containment failure or the offsite radiological release. Often, the response of containment and the radiological release (when it is quantified) is based on APETs or CETs, which are logic-based, simplified approximations to complex interrelated phenomena. While this APET/CET approach allows for the approximate quantification of many probabilistic accident pathways, it can sacrifice realism and relies on prescribed event sequences. The use of MELCOR in a probabilistic simulation-based approach may provide a number of advantages, including the following:

Leveraging Opportunities:

Both Brookhaven National Laboratories (BNL) and Sandia National Laboratories have expressed interest in collaboration on this effort. These laboratories have significant experience in the areas of PRA, severe accidents, and consequence analysis. In addition, BNL, Idaho National Laboratories and Ohio State all have ongoing work related to Level 2 PRA modeling.

- integration of phenomena-based modeling into risk quantification
- reduced reliance on a simplified or qualitative large early release frequency (or large release frequency in the case of advanced reactors)
- replacement of the APET/CET approach with a more defensible and consistent phenomenological analysis for evaluating accident progression
- greater flexibility in considering alternative risk metrics (e.g., a continuous curve for allowable dose versus event likelihood)
- increased ability to implement non-static PRA advancements (e.g., digital I&C, human reliability analysis)
- a greater long-term reliance on risk-significant accident sequences (as opposed to design-basis accident sequences)
- the potential for important related insights in Level 1 PRA modeling and the handling of errors of commission

This work is closely related to a number of other ongoing agency efforts, including the following:

- development of simplified Level 2 models for reviewers and inspectors
- the State of the Art Reactor Consequence Analysis Project
- the faster-than-real time incident response tool development effort

Planned Schedule:
- Initiation of staff-led initial scoping study – October 2008
- Workshop on tool uses and desired capabilities – February 2009
- Initiation of tool development – May 2009

Deliverables:
- Staff white paper documenting initial scoping study and workshop summary – March 2009
- Tool development plan – September 2009

These projects are scheduled for completion in a timeframe consistent with informing the proposed activity.

FY 2009 activities will begin with a scoping study to evaluate both methodological and implementation-oriented issues associated with the use of direct simulation in Level 2 PRA. The study will address uncertainties in scenario characteristics (e.g., how the timing of key events should be treated) as well as uncertainties in phenomenology (e.g., how model uncertainties should be treated). In addition, a workshop will be held focusing on uses and desired capabilities of the tool to be developed. Longer term efforts will focus on the following:

- developments for a fast-running phenomenology-based Level 2 tool
- an assessment of what characteristics are needed for Level 3 analysis and whether the agency's existing tools can meet those needs

2.4.6 Advanced Fabrication Techniques

Many new fabrication and construction techniques have been developed for shipbuilding, large civil structures, and general component manufacturing applications since the existing commercial nuclear fleet was completed. Several of these techniques are being considered, or have already been proposed, for subsequent construction of new LWR systems, structures, and components in the US. Other techniques may not be sufficiently mature until Generation IV and GNEP reactors are planned for construction. In many cases, these techniques hold the promise of reducing capital costs and construction times compared to existing nuclear plants, while simultaneously improving quality by either

Planned Schedule
FY 2008:
- Coordinate with DOE and nuclear industry to identify viable techniques
- Gain expertise in techniques and gauge potential safety and regulatory impacts
- Identify technical and regulatory issues

FY 2009:
- Conduct systematic scoping study
- Create detailed research plan to resolve technical issues

Deliverables
- Report documenting viable fabrication techniques and possible technical and regulatory issues– March 2008
- Report summarizing scoping study results – March 2009
- Report summarizing detailed research plan – September 2009

minimizing the amount of site construction necessary or enhancing the component performance within the intended environment.

Examples of somewhat recent construction advancements that may be applicable to nuclear applications include the use of steel-plate reinforced concrete structures; advanced concrete admixtures; high deposition rate welding; hot isostatic pressing; robotic welding; open-top construction; pipe bending versus weld elbows; cable splices; and prefabrication, preassembly, and modularization. Component manufacturing advancements include polymeric, diffusion, and thermal spray coatings to increase wear resistance and corrosion prevention, improve surface finish and reduce fouling. Nano-coatings are also starting to be used in commercial applications. In concert with these new techniques, many industries (e.g., cement and materials) are moving from prescriptive mix design specifications to performance-based specifications.

However, it is currently not known if these advanced construction fabrication techniques and the move to performance-based specifications result in any potential performance implications that are unique to nuclear applications. It is possible that some of these practices could affect both the NRC's processes for monitoring nuclear facility construction and the long-term performance of structures and components. Additionally, there may be unintended consequences associated with some of these methods including potential new failure modes, reduction in safety margins, and new component and subsystem interactions that could decrease overall system performance. For example, high deposition rate welding could lead to fundamentally different weld microstructures that may be more susceptible to certain degradation mechanisms than seen with historical welding techniques.

In FY 2007 and 2008, the NRC will coordinate with both DOE and the nuclear industry to identify viable construction and component manufacturing techniques that are being considered for new reactor construction. Also, several promising techniques under development that could support later (i.e., Generation IV) reactor construction will be identified. Staff will develop an understanding of these techniques and their impact on safety and regulatory processes in FY 2007 and 2008 to support a preliminary identification of technical and regulatory issues.

In FY 2009, staff will conduct a more systematic scoping study to identify and prioritize technical issues that may have adverse nuclear safety ramifications. This study will consider the performance of each technique under both relevant laboratory conditions and within existing commercial applications. An important aspect of this study will be to evaluate the effect of the nuclear operating environment on component/structural performance degradation. The objective will be to identify issues that may be unique to nuclear applications and determine if these techniques may cause any unintended consequences. The use of performance-based specifications will also be assessed to determine the sufficiency of this approach for nuclear construction and fabrication. For example, advanced concrete materials are expected to be used in new nuclear plant construction which need to be evaluated to ensure acceptable performance.

If necessary, a detailed research plan in this area will be developed in FY 2009 to resolve outstanding technical issues identified by the

Leveraging Opportunities

- DOE has expressed interest and has previously sponsored work to identify advanced fabrication techniques.
- EPRI has expressed interest in potential collaboration on technical issues.

scoping study. This plan will prioritize issues and also identify which research should be conducted by the NRC. Understanding the relative safety significance of new reactor systems and components would assist prioritization and increase the efficiency of this evaluation. Findings from NRC-sponsored research activities identified as part of these scoping evaluations will be structured to support staff combined license application (COLA) reviews and inspections, tests, analyses, and acceptance criteria (ITAAC) closeout. The research will also allow regulatory guidance (e.g., equipment qualification, quality control, and quality assurance) to be updated to reflect the use of these new techniques in nuclear power plant construction. Staff will also coordinate with industry to identify research issues associated with technical basis development. Research objectives will be informed by these issues.

DOE has expressed interest in this topic for its potential to reduce reactor construction costs while maintaining conformance with the NRC's regulatory processes[16]. EPRI has also encouraged NRC work in this area and has further indicated that regulatory acceptance of these advanced techniques could become critical to meeting new reactor cost and schedule goals[17]. EPRI has also offered to collaborate on technical issues related to validating these methods for use during new plant construction.

2.4.7 Extended In Situ and Real-time Inspection and Monitoring Capabilities

The last 15 years has witnessed a revolution in manufacturing and processing techniques which has resulted in miniaturized, cost-effective, and advanced sensors capable of performing real-time monitoring of critical systems and components. These sensors have seen widespread use in automotive, chemical processing, aerospace, and a variety of other commercial industries. Many commercial nuclear and material facilities, however, rely on technology developed during initial construction in the 1970s and 1980s. The possibility exists to greatly expand the monitoring and evaluation of critical systems and components both during normal and accident conditions to provide early and accurate information and better inform subsequent automated and human responses. Regulatory acceptance of advanced inspection and monitoring capabilities could benefit both the NRC and industry by more accurately assessing current plant performance and also by increasing the efficiency and reliability of new plant construction.

For example, in situ, real-time monitoring techniques could lead to more effective and reliable aging management of reactor materials by providing more frequent examinations while minimizing personnel radiation exposures. Improved capability to perform inspections and repairs online, in concert with technology advances that increase output and further reduce forced outage rates could also support fleet-wide average capacity factors increases beyond 90 percent. Additionally, in situ methods for monitoring fabrication could reduce defect rates and rework time which would result in improved efficiencies and performance during new reactor construction and subsequent operation. Also, real-time sensor technology coupled with advanced performance assessment methods (e.g., environmental modeling) could benefit licensees by establishing a basis for lower decommissioning costs.

As part of the DOE Nuclear Energy Research Initiative (NERI), a number of these new sensors and monitoring and diagnostic methods have been investigated. Many of these sensors are designed to support the needs of both new and advanced LWRs and high-

[16] ADAMS Accession No. ML071930343
[17] ADAMS Accession No. ML071900353

temperature gas reactors. The joint "U.S. Department of Energy/Nuclear Power Industry Strategic Plan for Light Water Reactor Research and Development," dated February 28, 2004[18], also describes the DOE plans to develop the following:

- technologies to conduct real-time performance monitoring of major nuclear plant components (e.g., reactor coolant pump seals)
- technologies, criteria, and methods to implement improved online monitoring to support operations and maintenance of plant equipment and components
- advanced inspection techniques for critical plant structures, systems, and components
- models of (and monitoring techniques for) environment-related phenomena and environmental variables affecting the rate of material degradation.

EPRI, ACRS, and ACNW&M all agree that the staff needs to maintain cognizance of developments within this technical area[19]. The current plan is to perform a scoping study in FY 2009 to identify, in concert with the nuclear industry, those sensors and techniques that have the most likely current commercial viability and also fill a critical inspection or monitoring need.

Possible candidates that will be considered include sensors to monitor:

- real-time material degradation
- in situ characterization of residual stress
- in situ, real-time ground water and soil conditions to assess long-lived radionuclide and associated chemical species concentrations
- fabrication monitoring and inspection
- in situ characterization of fuel properties
- severe accident conditions

Planned Schedule
FY 2009
- Conduct scoping study to identify, in concert with the nuclear industry, commercially-viable techniques
- Develop research plan for characterizing and evaluating most promising techniques

FY 2010
- Initiate research plan

Deliverables
- Staff white paper identifying sensors and techniques most applicable for commercial nuclear service – May 2009
- Research plan– September 2009

Examples of important severe accident parameters that warrant investigation of advanced monitoring techniques include core temperatures up to core failure and relocation, pressurized water reactor vessel water levels, and steam generator water levels during loss-of-direct-current events. The use of miniature sensors released after the accident initiates will also be explored. Wireless communications technology is expected to be essential for many of these advanced sensors and may be beneficial for providing local monitoring during an accident by both plant and NRC staff.

A few of the most promising sensors or techniques for nuclear applications will be selected for characterization and evaluation, starting in FY 2010. The evaluation will focus on performing confirmatory research on regulatory and safety aspects so that staff can verify the reliability, accuracy, and acceptability of these sensors/techniques for nuclear power plant service. A detailed research plan for conducting any necessary evaluations will be

Leveraging Opportunities

DOE and EPRI have expressed interest in cooperating and/or collaborating in this area.

[18] ADAMS Accession No. ML071920122
[19] ADAMS Accession Nos. ML071900353, ML071790071, and ML071360105, respectively

completed in FY 2009 after the scoping study is completed. The staff also plans to work with the nuclear industry during this time to identify necessary industry-sponsored research to support regulatory decisionmaking. Both EPRI and DOE have expressed interest in exploring possible activities for cooperation or collaboration within this technical area[20].

2.4.8 Offsite Mitigation Strategies

Plant improvements, procedures, training and offsite protective measures (emergency planning) have reduced the risk (i.e., public health consequences) from severe accidents at nuclear power plants. Even so, in the event of an accident with containment failure (even delayed failure) the potential consequences of a radioactive release are not trivial and mitigation of those releases would be a national priority. Technologies to utilize airborne mitigation systems are currently being developed to address environmental (including radiological aerosol) releases. The application of those mitigation systems to potential nuclear plant releases is a feasible approach as part of a Federal response capability.

Leveraging Opportunity:

In a June 18, 2007 letter, EPRI expressed interest in working with the NRC on this issue:

"EPRI has considered some of these strategies as part of its work on improved off-site consequence modeling and code improvement, and believes it could be a fruitful area for further work."

"EPRI would appreciate the opportunity to work with RES in this area."

This activity will be informed by a recently initiated NRC project at Sandia National Laboratories to investigate the effectiveness of onsite conventional-type water spray systems. This program involves analysis, small-scale testing, and integral effects testing. This work is closely related to the broader FY 2009 activity identified here.

Research in FY 2009 will focus on monitoring external activities related to the development of technologies (e.g., scavenging agents) for the capture and cleanup of radioactive material and the demonstration of their effectiveness for a variety of release and meteorological conditions. Examples of other entities that may be engaged on this topic include the national laboratories and U.S. defense agencies such as the Defense Advanced Research Projects Agency.

Deliverable:

End of FY 2009 – White paper describing a comprehensive review of domestic and international activities in this area, a catalogue of promising technologies, and to the extent practicable, order-of-magnitude estimates of radioactive aerosol reduction factors.

[20] ADAMS Accession Nos. ML071900353 and ML071930343