POLICY ISSUE
INFORMATION

March 28, 2010 SECY-10-0034

FOR: The Commissioners

FROM: R. W. Borchardt
Executive Director for Operations

SUBJECT: POTENTIAL POLICY, LICENSING, AND KEY TECHNICAL ISSUES FOR SMALL MODULAR NUCLEAR REACTOR DESIGNS

PURPOSE:

To inform the Commission of potential policy, licensing, and key technical issues that may require Commission consideration to support future design and license review applications for small modular reactors (SMRs), and the staff's plans for developing plans for their resolution.[1]

SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) staff has been meeting with the Department of Energy (DOE) and, as resources allowed, with individual SMR designers to discuss potential policy, licensing, and key technical issues for SMR designs. As a result of these pre-application activities and earlier work by the NRC staff and Commission, the NRC staff has identified a number of potential policy and licensing issues. The enclosure to this paper provides a summary description of these potential policy issues for Commission information. The discussions are consistent with information provided in previous Commission papers and other related agency documents. The references provided in Attachment 2 to the enclosure include these key Commission documents.

The NRC staff plans to develop proposed resolutions to these potential policy issues and will inform the Commission and other stakeholders of its activities and progress on resolving them. Although approaches to potential resolutions are described, the enclosure does not include proposed resolutions for any of the issues. As information is available and the evaluations

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[1] A design review application could involve a request for a design approval or design certification under Title 10 of the *Code of Federal Regulations* Part 52 (10 CFR Part 52). A license review application could involve a request for a combined license, manufacturing license, or early site permit under 10 CFR Part 52 or a request for a construction permit and operating license under 10 CFR Part 50.

progress, the NRC staff will prepare future papers that propose potential resolutions or paths to resolution of policy issues to support the Next Generation Nuclear Plant (NGNP) and other SMR review activities. In addition, the staff will inform the Commission in a timely manner of additional issues when they are identified.

BACKGROUND:

As discussed in SECY-08-0019,[2] nuclear reactor designers are developing new nuclear reactor designs and technologies, and have notified the NRC that they may submit design and license applications for some of their SMR designs to the NRC as early as FY 2011. These include (1) a license application for construction and operation of a helium-cooled very-high-temperature reactor in connection with the NGNP project established by the Energy Policy Act of 2005; (2) a design certification (DC) application for the International Reactor Innovative and Secure pressurized-water reactor (PWR) design; (3) a DC application and possible combined license (COL) application for the NuScale Power Reactor PWR design; (4) a DC application for the mPower PWR design; (5) a design approval application for the Super-Safe, Small and Simple sodium-cooled fast reactor (SFR); and (6) prototype COL and manufacturing license applications for the Power Reactor Inherently Safe Module SFR design. Other innovative reactor design and site development activities could lead to the submission of additional design and license review applications for SMRs to the NRC within the next 10 years, but they are not addressed in this paper because of the preliminary status of their development.

The Commission's final policy statement on the regulation of advanced reactors[3] states:

> To provide for more timely and effective regulation of advanced reactors, the Commission encourages the earliest possible interaction of applicants, vendors, other government agencies, and the NRC to provide for early identification of regulatory requirements for advanced reactors and to provide all interested parties, including the public, with a timely, independent assessment of the safety and security characteristics of advanced reactor designs. Such licensing interaction and guidance early in the design process will contribute towards minimizing complexity and adding stability and predictability in the licensing and regulation of advanced reactors.

Furthermore, in the NGNP Licensing Strategy,[4] the Commission stated that in order to implement the NGNP licensing strategy successfully, and meet the congressionally-mandated operation date of 2021, the NRC and DOE needed to implement a pre-application review to identify and resolve policy, regulatory, and key technical issues for the NGNP. Early resolution or identification of a clear path to resolution for issues related to SMRs will enable designers to incorporate appropriate changes during the development of their designs before submitting a design or license review application. Accordingly, the NRC staff has been interacting with DOE on the NGNP and, on a limited basis in accordance with resource availability, with the designers of new SMRs to become familiar with the new designs and technologies, and to provide feedback to DOE and pre-applicants on potential key design, technology, and licensing issues

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[2] SECY-08-0019, "Licensing and Regulatory Research Related to Advanced Nuclear Reactors," dated February 14, 2008. (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML091130253 (publicly available), ML073370326 (non-publicly available) and ML073370532 (non-publicly available)). All documents referenced in this paper are available in ADAMS on the NRC's web page (www.nrc.gov) under the accession number provided, except where noted.

[3] Policy Statement on the Regulation of Advanced Reactors: Final Policy Statement, 73 Federal Register 60,612, and 60,616 (October 14, 2008)

[4] "Next Generation Nuclear Plant Licensing Strategy - A Report to Congress," dated August 2008 (ADAMS Accession No. ML082290017)

and on their technology development program plans. These interactions will also provide information to determine NRC infrastructure development and research needs and plans.

DISCUSSION:

The NRC staff has been meeting with DOE and, as resources allowed, with individual SMR designers to discuss potential policy, licensing, and key technical issues for SMR designs. The NRC staff also conducted an SMR workshop in October 2009[5] with SMR designers, DOE, the Nuclear Energy Institute, and other stakeholders to discuss potential policy issues that are common to more than one design. The staff encouraged the participants to work together or with other organizations to generically address issues common to all nuclear designs, SMRs, or specific technology groups (i.e., integral PWRs) in order to focus the issues, propose and obtain consistent resolutions, and effectively use resources. As a result of these pre-application activities and earlier work by the NRC staff and Commission, the NRC staff has identified a number of potential policy and licensing issues based on the preliminary design information provided by pre-applicants and discussions with the designers and DOE regarding their proposed approaches to addressing key issues. The enclosure describes those potential policy issues that the staff has identified. In general, these issues result from the key differences between the new designs and current-generation pressurized-water reactors (such as size, moderator, coolant, fuel design, and projected operational parameters), but they also result from industry-proposed review approaches and industry-proposed modifications to current policies and practices. This paper addresses only those potential policy and licensing issues for which resolutions may require Commission consideration. It does not address key technical issues related to these designs unless their importance to the design and the potential impact of policy issue resolutions require such discussion. The description and references provided in the enclosure are not intended to be all inclusive. In addition, although approaches to potential resolutions are described, the enclosure does not include proposed resolutions for any of the issues.

The NRC staff plans to develop proposed resolutions to these issues by continuing to obtain information from DOE, potential design and license applicants, and other sources (both domestic and international); identifying and developing proposals for the resolution of policy issues; and where appropriate, preparing papers proposing resolutions of these issues with recommendations for consideration and approval by the Commission. Although the staff discusses a number of potential policy issues concerning SMRs in the enclosure, it has identified some key issues that it considers most important to resolve by FY 2011 or FY 2012 in order to support the design development of the NGNP and integral PWRs. The following is a brief description of these key issues. They are discussed in greater detail in the enclosure along with the other potential policy issues that may need to be addressed as the NRC staff conducts its SMR reviews.

Implementation of the Defense-In-Depth Philosophy for Advanced Reactors

The Commission has had a long-standing policy of ensuring that defense-in-depth (DID) is incorporated into the design and operation of nuclear power plants. The requirements in 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” incorporate DID measures specific to light-water reactors (LWRs). Although integral PWRs employ the more traditional DID approach of LWRs in their designs, non-LWR SMR designers propose to use

[5] “Summary of Workshop on Small- and Medium-Sized Nuclear Reactors (SMRs),” U.S. Nuclear Regulatory Commission, October 22, 2009. (ADAMS Accession No. ML092940138)

different approaches to establish DID barriers for their designs. This can be seen in their approaches to address technical issues such as redundancy of key safety-related components and containment functional capability. The DID measures have been determined on a case-by-case basis for non-LWRs licensed in the past. Preventive or mitigative compensatory measures may need to be incorporated into the design or operation of certain SMRs to account for uncertainties in design or operational capability of the facility. In FY 2010 and FY 2011, the NRC staff will review pre-application submittals concerning DID that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, consider approaches to DID proposed by the domestic and international community, and determine whether preventive or mitigative compensatory measures may be needed for SMR designs to account for uncertainties in design or operational capability of the facility. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning DID in FY 2011 to support development of the NGNP or other SMR designs.

Appropriate Source Term, Dose Calculations, and Siting for SMRs

Accident source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. Other radiological source terms are used to show compliance with regulations on dose to workers and the public. Design and license applicants and the NRC will need to establish appropriate bounding source terms for high-temperature gas-cooled reactors and other SMRs. There may also be source-term issues associated with the multi-module aspect of SMRs where modules share structures, systems, and components (SSCs). For example, the Commission may have to determine when it would be appropriate to base the bounding source term on an accident in a single module and when possible sharing of SSCs require the evaluation of core damage in and potential releases from more than one module. In FY 2010 and FY 2011, the NRC staff will review pre-application submittals concerning source-term issues that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulations or propose new regulatory guidance concerning the source term and site suitability for an SMR in FY 2011 to support development of the NGNP and other SMR designs.

Appropriate Requirements for Operator Staffing for Small or Multi-Module Facilities

Some SMR designs may use multiple modules at one site, but current regulations do not address the possibility of more than two reactors being controlled from one control room. In addition, SMR designers have indicated that they are considering whether their designs can operate with a staffing complement that is less than that currently required by the Commission's regulations. Other potential SMR policy issues include the possible need for requirements on control room staffing during refueling operations, reactor staff who interact with an interconnected manufacturing plant, supervisory staff, shift work, and training. In FY 2010 and FY 2011, the NRC staff will review pre-application submittals concerning operator staffing and associated control room design that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with human factors and instrument and controls experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or staff positions or propose new guidance concerning the operator staffing for an SMR in FY 2012 to support development of the NGNP and other SMR designs.

Security and Safeguards Requirements for SMRs

Because many SMRs are still in early developmental stages and the designs are not yet fixed, SMR designers have a unique opportunity to determine the appropriate design basis threat; develop emergency preparedness; and integrate physical security protection, cyber security protection, and material control and accounting (MC&A) measures with the design and operational requirements during the design process and during the development of the a license applicant's physical security and MC&A programs and systems. SMR designers are expected to integrate security into the design and will need to conduct a security assessment to evaluate the level of protection provided, including safeguards aspects of SMR-related fuel cycle and transportation activities. The DOE, SMR designers, and potential operators have raised issues regarding the appropriate number of security staff and size of the protected area. In FY 2010 and FY 2011, the NRC staff will review pre-application submittals concerning safeguards that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with safeguards experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning safeguards for an SMR in FY 2011 to support development of the NGNP and other SMR designs.

The staff is developing detailed resolution plans for each issue discussed in this paper, taking into account factors such as whether resolution of the issue is critical to the development of the NGNP or integral LWR designs; the number of affected technology groups and design centers; the potential effect on design decisions; the potential need for legislation, rulemaking, or policy changes; the potential need for confirmatory research; the participation and cooperation of applicants, other Government agencies, professional societies, and other stakeholders; the potential effect on the schedule for prototype plants or commercial deployment; and the dependencies on other policy or technical issues (e.g., development of source-term models). The staff will refine and implement the resolution plans for each issue as it receives additional information from DOE, pre-applicants or applicants, or other sources in FY 2010 and FY 2011, and as the staff assesses possible solutions to the technical and policy issues. The staff will address technical issues using established processes, including public participation, for issuing regulatory guidance, and will provide future papers to the Commission describing the proposed resolutions and the NRC staff positions and recommendations regarding each of the major policy issues. The staff will provide information to the Commission and other stakeholders regarding its activities and progress on resolving the policy and key technical issues using established mechanisms such as public meetings, postings on the NRC web page, and routine reporting vehicles such as the quarterly updates on the status of new reactor review activities.

RESOURCES:

The resources allocated to conduct the activities described in this paper (including those for supporting offices) are included in budgeted activities listed below related to the reviews of SMRs. There is $14.2M, including 29.4 full time equivalents (FTEs) budgeted in FY 2010. There is $18.8M, including 49 FTE, included in the FY 2011 Presidents Budget. The resources for FY 2012 and beyond will be requested using the planning, budgeting, and performance

management process as the staff better understands the complexity of these issues and their effect on the SMR designs.

	FY 2010			FY 2011		
	Contract $	**Total FTE**	**Amount**	**Contract $**	**Total FTE**	**Amount**
Total	$9,756	29.4	$14,195	$11,430	49.0	$18,819
NRO	3,166	12.9	5,114	5,994	26.2	9,945
NSIR	0	0.5	75	0	1.8	271
RES	6,590	16.0	9,006	5,436	21.0	8,603

CONCLUSIONS:

The NRC staff will continue its pre-application activities on the NGNP and its interactions with the designers of other SMRs to further identify and resolve policy, licensing, and key technical issues. The staff is developing detailed resolution plans for each issue. As the plans are implemented, the staff will prepare papers that propose resolutions or paths to resolution of policy issues to support the NGNP and other SMR review activities. In addition, the staff will inform the Commission in a timely manner of additional issues when they are identified.

COORDINATION:

This paper has been coordinated with the Office of the General Counsel, which has no legal objection, and with the Office of the Chief Financial Officer.

/RA by Bruce S. Mallett for/

R. W. Borchardt
Executive Director
for Operations

Enclosure:
Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs

POTENTIAL POLICY, LICENSING, AND KEY TECHNICAL ISSUES FOR SMALL MODULAR NUCLEAR REACTOR DESIGNS

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Enclosure

POTENTIAL POLICY, LICENSING, AND KEY TECHNICAL ISSUES FOR SMALL MODULAR NUCLEAR REACTOR DESIGNS

1.0 Introduction

The U.S. Nuclear Regulatory Commission (NRC) staff has been conducting pre-application interactions with the U.S. Department of Energy (DOE) on the Next Generation Nuclear Plant (NGNP) and, on a limited basis in accordance with resource availability, with the designers of other new small modular nuclear reactors (SMRs). The NRC staff has identified a number of potential policy and licensing issues that may require resolution during the review of design and license applications[1] for some of these designs. The reactor designs included in this review include the following: [2]

- DOE's NGNP, a helium-cooled very-high-temperature reactor (VHTR)
- Pebble Bed Modular Reactor (Pty) Limited's Pebble Bed Modular Reactor (PBMR), a 400 megawatt-thermal (MWt) (165 megawatt-electric (MWe)) pebble bed gas-cooled reactor design
- General Atomics' Gas-Turbine Modular Helium Reactor (GT-MHR), a 600 MWt (285 MWe) prismatic gas-cooled reactor design
- AREVA NP, Inc.'s AREVA's New Technology Advanced Reactor Energy System (ANTARES), a 600 MWt (285 MWe) prismatic gas-cooled reactor design
- Westinghouse Electric Company's International Reactor Innovative and Secure (IRIS), a 1000 MWt (335 MWe) pressurized light-water reactor (PWR) design with an integral nuclear steam supply system (NSSS)
- NuScale Power, Inc.'s NuScale Power Reactor (NuScale), a 160 MWt (45 MWe) natural-circulation PWR design with an integral NSSS
- Babcock & Wilcox Company's mPower reactor design, a 400 MWt (125 MWe) PWR design with an integral NSSS
- Toshiba Corporation's Super-Safe, Small and Simple (4S) 30 MWt (10 MWe) sodium-cooled fast reactor (SFR) design
- GE Hitachi Nuclear Energy's Power Reactor Inherently Safe Module (PRISM) 471 MWt (155 MWe) SFR design

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[1] A design review application could involve a request for a design approval or design certification under Title 10 of the *Code of Federal Regulations* Part 52 (10 CFR Part 52). A license review application could involve a request for a combined license, manufacturing license, or early site permit under 10 CFR Part 52 or a request for a construction permit and operating license under 10 CFR Part 50.

[2] The power levels presented represent nominal values of the reference designs to provide information on the size of the designs. The actual design values may change as the design is finalized. Additional descriptions of the designs and a discussion of the interrelationship between the NGNP and other gas-cooled reactor designs are provided in Attachment 1 to this enclosure.

Other reactor design development activities could result in evaluation of other SMR designs sometime in the next 10 years, but they are not addressed in this paper because of the preliminary status of their design development.

As a result of its pre-application activities and earlier work by the NRC staff and Commission, the NRC staff has identified a number of potential policy, licensing, and key technical issues based on review of the preliminary design information provided by the pre-applicants and discussions with the designers and DOE regarding their proposed approaches to addressing key issues. In developing this list of issues, the NRC staff considered the following:

- policy issues previously identified to the Commission,
- the unique aspects of these designs,
- the applicability of current regulatory requirements and guidance to these designs,
- its previous and current reviews of light-water reactor (LWR) and non-LWR designs,
- international experience with licensing and operation of advanced reactor designs,
- operating experience of commercial, test, and research reactors, and
- the results of available probabilistic risk assessments (PRAs).

The NRC staff has met with individual SMR designers to discuss potential policy, licensing, and key technical issues for their specific designs. The NRC staff also conducted an SMR workshop on October 8-9, 2009, to discuss potential policy issues that are common to more than one design with SMR designers, DOE, the Nuclear Energy Institute (NEI), and other stakeholders. The staff encouraged the participants to work together or with other industry organizations to generically address issues common to all nuclear designs, SMRs, or specific technology groups (i.e., integral PWRs) in order to focus the issues, propose and obtain consistent resolutions, and effectively use resources. Early resolution or identification of a clear path to resolution for these issues will enable SMR designers to incorporate appropriate changes during the development of their designs before submitting a design or license application.

In general, these issues result from the key differences between the new designs and current-generation LWRs (such as size, moderator, coolant, fuel design, and projected operational parameters), but they also result from industry-proposed review approaches and industry-proposed modifications to current policies and practices. As indicated earlier, some of these issues are common to all nuclear reactor designs, and may be resolved in connection with consideration of these issues for all reactors. The following sections describe those issues that the NRC staff considers to be potential policy and licensing issues that the agency will likely have to address while determining the acceptability of these unique designs during design and license reviews, should an application be submitted. This paper does not address key technical issues related to these designs unless their importance to the design and the potential impact of policy issue resolutions require such discussion. The references provided in Attachment 2 of this enclosure are key Commission papers and other documents that address these issues.[1] The description and references provided in the attachment are not intended to be all inclusive, and will be further discussed in future papers, as necessary.

[1] Attachment 2 provides the full title, date issued, and ADAMS accession number for all references.

The staff is developing resolution plans for each issue discussed in this paper taking into account factors such as whether resolution of the issue is critical to the development of the NGNP or integral LWR designs; the number of affected technology groups and design centers; the potential effect on design decisions; the potential need for legislation, rulemaking, or policy changes; the potential need for confirmatory research; the participation and cooperation of applicants, other Government agencies, professional societies, and other stakeholders; the potential effect on the schedule for prototype plants or commercial deployment; and the dependencies on other policy or technical issues (e.g., development of source term models). The staff will refine and implement the resolution plans for each issue as it receives additional information from DOE, pre-applicants or applicants, or other sources in FY 2010 and FY 2011, and as the NRC staff assesses possible solutions to the technical and policy issues.

The NRC staff is providing an initial characterization of the issues in terms of scope (generic or specific technology group/design center), importance, and likely timing for subsequent Commission papers (FY 2011, FY 2012, or FY 2013 or beyond). The specific resolution plans developed for the issues may change as additional information is collected and assessed. In addition, activities undertaken by the industry or other stakeholders may inform the NRC staff in developing resolution plans and could revise the above initial characterization. For example, the American Nuclear Society has created a special committee to prepare possible positions on various regulatory issues related to small- and medium-sized reactors. This activity, as well as those of other groups and designers, are in preliminary stages and will likely affect both the scope and timing of the resolution plans being developed by the NRC staff. The staff will provide information to the Commission and other stakeholders regarding its activities and progress on resolving the policy and key technical issues using established mechanisms such as public meetings, postings on the NRC web page, and routine reporting vehicles such as the quarterly updates on the status of new reactor review activities.

2.0 Licensing Process Issues for Small Modular Nuclear Reactors

2.1 License for Prototype Reactors

Scope: Design specific
Importance: High
Issue Paper: FY 2013 or beyond

If the progress of an SMR research and development (R&D) program does not fully support an NRC decision on a license application for the proposed commercial version of the design, the design or operation of the first unit may need to include preventive or mitigative compensatory measures to account for uncertainties in the design or operational capability (see 10 CFR 50.43(e)). In addition, the NRC may require special confirmatory tests and measurements in the license in order to confirm that the facility operates in accordance with the designer's analyses. License conditions could be imposed and/or features added to the plant to increase safety margin until such time as the operation of the prototype unit or other testing programs confirm certain aspects of the design and equipment performance. These license conditions could, for example, limit the plant to less than full power, place restrictions on operational temperature, or require more extensive startup or operational testing. Another alternative could be to use initial plant startup as a means to test and confirm plant safety features in lieu of conducting R&D before plant licensing. If such an alternative is chosen, the

scope and nature of the startup or operational test program would need to be agreed upon, but this alternative could involve an incremental licensing approach during startup operations, with power and temperature uprates allowed when confirmatory measurements of core temperature and plant parameters confirm design expectations and predictions. License applicants and the NRC staff have not relied on the construction and operation of a licensed prototype reactor to confirm design assumptions or to even supplement pre-licensing R&D since the early period of the evolution of commercial nuclear power plants. The use of these provisions in NRC regulations may involve policy issues for Commission consideration. The NRC staff also discussed this issue in SECY-02-0180.

This issue was raised as a potential issue for the NGNP in the August 2008 Licensing Strategy, but the staff believes that it could also be applicable to other new, first-of-a-kind designs. The staff believes that resolution for this issue need not occur until after a license application is submitted because the extent of necessary preventive or mitigative compensatory measures and confirmatory testing needs for a prototype will not be known until after the staff has reviewed the applicant's demonstration test program for the design and the proposed operational test program that supports the license. Once a license application is received, the NRC staff will review the prototype design, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and determine whether compensatory measures are needed for the design to account for uncertainties in design or operational capability of the facility. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning the license for the prototype in a timeframe consistent with the licensing schedule.

2.2 License Structure for Multi-Module Facilities

Scope: Generic
Importance: Medium
Issue Paper: FY 2013 or beyond

Issues with the written structure of a design certification or license for multi-module facilities may arise during the review of the application for a modular reactor design, particularly when one module can begin operation while other modules are being built and installed. For example, the NuScale Power reactor design, which could be a multi-module facility, raises issues pertaining to the effective duration of a combined license (COL) issued for such modular reactor designs. Section 52.103(g) of 10 CFR states: "[i]f the combined license is for a modular design, each reactor module may require a separate finding [that the acceptance criteria of the COL are met] as construction proceeds." In the case of NuScale where the designer plans to submit a design certification application for a 12-module facility, a single module may be put into operation, but the other modules may not be put into operation for a significant amount of time, depending on factors such as resource limitations, the need for power, or upgrades to transmission lines. In addition, it is possible that an applicant may submit an application for design certification of a facility that can employ a single reactor or can consist of multiple reactor modules. The license of other SMRs, such as the mPower design, may also be affected, depending on how the applicant submits the license application. Although 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," addresses some aspects of modular facilities, the use

of these provisions may involve policy issues or identify possible regulatory changes requiring Commission consideration and approval.

Although resolution of these issues before submittal of a design certification or license application may be more important to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of these issues need not occur until after a licensing application is submitted because it concerns activities that will need to be addressed during an operating license review. Once a license application for a multi-module facility is received, the NRC staff will review the application, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, and discuss design-specific proposals to address this matter. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning the license for the multi-module facility in a timeframe consistent with the licensing schedule.

2.3 Manufacturing License Requirements for Future Reactors

Scope: Generic
Importance: Low
Issue Paper: FY 2013 or beyond

The NRC staff has identified a potential policy issue regarding whether a manufacturing license would be allowed or possibly required in addition to a design certification. There are likely jurisdictional issues with respect to requiring and issuing a manufacturing license if the manufacturing is taking place in a foreign country. For example, the PBMR could be fabricated in South Africa and the Toshiba 4S could be manufactured in Japan. B&W plans to fabricate its mPower modules offsite in its U.S. and Canadian facilities, using its integrated manufacturing infrastructure. NuScale Power currently plans to fabricate the modules offsite within the United States, and ship the reactor vessel and steel containment in pieces to the site. The NRC staff may need to consider conditions on an import license with respect to access by NRC inspectors to verify compliance of reactors manufactured outside of the United States.

Also, the regulations for a manufacturing license granted in accordance with 10 CFR Part 52 are structured for a complete facility, including the NSSS and balance-of-plant (BOP). This regulatory structure reflects the only experience the NRC has had with reviewing and issuing a manufacturing license (i.e., Offshore Power Systems' ML-1 for the Floating Nuclear Power Plant, issued in 1982). Issuing a manufacturing license authorizing the manufacture and transport of only major portions of the plant (e.g., the NSSS) and combining these with structures and systems built at specific sites may involve potential policy issues that would require Commission consideration.

Although the PBMR, Toshiba 4S, PRISM, mPower, and NuScale reactors are all candidates for a manufacturing license because of size, manufacturing plans and location, and transportation considerations, only GE-Hitachi currently proposes to submit a manufacturing license for its PRISM SFR design. The staff is currently directing its focus on issues concerning the NGNP and integral PWRs. Therefore, the NRC staff has assigned a low priority to resolution of this issue.

3.0 Issues Concerning Design Requirements for Small Modular Nuclear Reactors

3.1 Implementation of the Defense-In-Depth Philosophy for Advanced Reactors

Scope: Generic (although more germane to non-LWRs)
Importance: High
Issue Paper: FY 2011

The Commission has had a long-standing policy of ensuring that defense-in-depth (DID) is incorporated into the design and operation of nuclear power plants. The requirements in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," incorporate DID measures specific to LWRs (e.g., a pressure-retaining, low-leakage containment). Although integral SMRs employ the more traditional DID approach of LWRs in their designs, non-LWR SMR designers propose to use different approaches to establish DID barriers for their designs. This can be seen in their approaches to address technical issues such as redundancy of key safety-related components and containment functional capability. For non-LWRs licensed in the past (e.g., Fort St. Vrain), DID measures have been determined on a case-by-case basis. Preventive or mitigative compensatory measures may need to be incorporated into the design or operation of certain SMRs to account for uncertainties in design or operational capability of the facility. Therefore, the NRC staff will need to determine appropriate DID measures and develop appropriate requirements and guidance to support design and license reviews of integral PWRs and non-LWR designs.

In SECY-09-0056, the NRC staff stated that it plans to integrate its position on DID with its positions on other policy and key technical issues for future reactor designs during its reviews. The staff plans to continue development of a position on DID along with development of other related Commission policy and technical positions, but it will defer activities to finalize a DID policy statement until it has gained additional experience and related insights from the NGNP or other non-LWR reviews.

The NRC staff believes that resolution of this issue is required to support the design development of the NGNP and potentially other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of the NGNP COL application. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning DID that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, consider approaches to DID proposed by the domestic and international community, and determine whether preventive or mitigative compensatory measures may be needed for SMR designs to account for uncertainties in design or operational capability of the facility. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning DID in FY 2011 to support development of the NGNP or other SMR designs.

3.2 Use of Probabilistic Risk Assessment in the Licensing Process for SMRs

Scope: Generic (although more germane to non-LWRs)
Importance: High
Issue Paper: FY 2013 or beyond

In the August 2008 NGNP licensing strategy, the Commission concluded that the best option for licensing the NGNP prototype would be to use a risk-informed and performance-based technical approach that employs the use of deterministic judgment and analysis, complemented by NGNP-specific PRA information. This licensing approach would, where possible, adapt the existing LWR technical requirements to address the acceptability of the NGNP design and establish requirements unique to the NGNP for those technical areas that existing LWR requirements and guidance do not address. The Commission concluded that once NGNP technology is successfully demonstrated through operation and testing of the NGNP prototype, and a quality PRA that includes data from operation of the prototype becomes available, greater emphasis on a design-specific PRA to establish the licensing basis and requirements will be a more viable option for licensing a commercial version of the NGNP reactor.

Design development and possible review approaches have been discussed with the NRC and proposed in other forums (i.e., draft consensus standards and international technical reports) that would place greater emphasis on the use of risk insights to identify licensing basis events and establish the safety classification of systems, structures, and components (SSCs) for reactor designs. This approach is consistent with a licensing approach described in SECY-03-0047 and approved by the Commission in its staff requirements memorandum (SRM) of June 26, 2003. However, in SECY-09-0056, the NRC staff discussed its plans to follow an approach consistent with the NGNP Licensing Strategy for licensing the prototype reactor while also testing and refining requirements and guidance for increased use of risk insights in the licensing process. Should an applicant submit a design for a facility license that uses an approach applying increased use of risk insights to establish the licensing basis before this effort is undertaken and evaluated, the use of this approach may involve policy issues requiring Commission consideration.

In addition, a number of issues related to the application of current risk-informed programs have been raised because of the lower risk estimates for the large LWRs currently under review. The two most common risk metrics used in current risk-informed applications are based on a core damage frequency (CDF) of 10^{-4}/year and a large, early release frequency (LERF) of 10^{-5}/year as surrogates for the Commission's quantitative health objectives. Risk estimates for new reactors are several orders of magnitude (1 to 3 for CDF; and 1 to 4 for radionuclide release frequency) lower than those for current designs when including internally initiated events and those externally initiated events that have been quantified. The lower risk values create challenges regarding how to apply acceptance guidelines for changes to the licensing basis and thresholds in the Reactor Oversight Process (ROP). The NRC staff provided a white paper to the Commission on February 12, 2009, that identifies the issues posed by the lower risk estimates for large LWRs in risk-informed applications and potential options for implementation. On March 27, 2009, NEI submitted its own white paper recommending no change to the current risk metrics. The NRC staff held a meeting to discuss these issues with stakeholders on September 29, 2009, and is drafting a Commission paper to discuss the issue and present policy options to the Commission. These issues are expected to be applicable to integral PWRs

as well. However, these risk metrics are not applicable to non-LWR SMRs, so the NRC will need to determine what risk metrics should be used for changes to the licensing basis and thresholds in the ROP for those designs.

Because the NRC has chosen to use a risk-informed and performance-based technical approach that employs the use of deterministic judgment and analysis, complemented by design-specific PRA information to review the first NGNP, resolution of this issue is not required to conduct the COL review described in the NGNP Licensing Strategy. In addition, the staff plans to employ a similar approach to review design and license applications for integral PWR designs. Therefore, the staff believes that resolution of this issue need not occur until after design or licensing applications are submitted that propose a review approach be used by the NRC staff that places greater emphasis on a design-specific PRA to establish the licensing basis and requirements.

3.3 Appropriate Source Term, Dose Calculations, and Siting for SMRs

Scope: Generic
Importance: High
Issue Paper: FY 2011

Accident source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. Other radiological source terms are used to show compliance with regulations on dose to workers and the public. The Commission has previously deliberated on the use of design-specific and event-specific source terms, provided there was sufficient understanding and assurance of plant and fuel performance and deterministic engineering judgment was used to bound uncertainties. The source terms for the integral PWRs may be based partly on source term information from current generation LWRs and insights gained from extensive state-of-the-art fission product experiments conducted to understand accident phenomena including fission product transport and release. The staff will assess what will be necessary to establish the basis for a scenario-specific approach and how uncertainties should be taken into account. In addition, design and license applicants and the NRC will need to establish appropriate bounding source terms for high-temperature gas-cooled reactors (HTGRs) and SFRs. This is discussed in more detail in Section 3.4 of this paper.

There may be regulatory issues that the Commission may have to consider regarding whether the site boundary dose acceptance criteria and associated dose calculations for use in evaluation of site suitability and emergency planning for SMR designs should be updated or amended, or whether new requirements should be established for SMRs. Current regulatory practice employs the siting dose criteria in 10 CFR 50.34 and 10 CFR Part 52 in conjunction with deterministic design basis accident analyses as the key input parameters for analyzing the effectiveness of the containment, determining site suitability, and preparing site emergency plans.

As discussed in the footnotes in 10 CFR 52.79(a), the current regulations on siting are based on deterministic evaluation of a large fission product release from a substantially melted core to an intact containment, with design leakage to the environment and calculation of cumulative dose to a reference person at two different locations offsite. These accident assumptions may not be

applicable for some SMR designs, which may call into question the applicability of the dose criteria as well.

In addition to the appropriate source terms for the SMR designs, the evaluation of site suitability may include consideration of the population density; use of the site environs, including proximity to man-made hazards; and the physical characteristics of the site, including seismology, meteorology, geology, and hydrology for the SMR designs. Therefore, there may be regulatory issues that the Commission may have to consider regarding whether the seismic and geologic siting criteria and earthquake engineering criteria should be updated or amended, or whether new requirements should be established for SMRs to incorporate advancements of earth science and earthquake engineering for use in evaluation of the site suitability for some SMR designs.

There may also be source-term issues associated with the multi-module aspect of SMRs where modules share SSCs. For example, the Commission may have to determine when it would be appropriate to base the bounding source term on an accident in a single module and when could possible sharing of SSCs require the evaluation of core damage in and potential releases from more than one module. Issues related to source term and risk evaluations for multi-module facilities may relate to policy and therefore, require Commission consideration.

The NRC staff believes that resolution of this issue is required to support the design development of the NGNP. Interrelated issues could also affect the design of integral PWRs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning source-term issues that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulations or regulatory guidance or propose new guidance concerning the source term for an SMR in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.

3.4 Key Component and System Design Issues for SMRs

This subsection provides examples of how resolutions to policy issues could impact key component and system design technical issues. When the time is right, the staff will present these to the Commission for a decision. At the time the issues are presented and the Commission has determined the appropriate resolution or resolution paths for the policy issues described in this paper, the NRC staff will address how these resolutions should be applied to address technical issues, using established processes, including public participation, for issuing regulatory guidance. In addition, the NRC staff expects that SMR applicants will provide information to the NRC staff showing how policy issue resolutions have been applied to addressing key technical issues when they submit design and license review applications, and the NRC staff will evaluate the acceptability of the implementation of the policy decisions in the designs. The NRC staff does not anticipate that these technical issues will require Commission consideration provided that the resolutions to SMR policy issues are appropriately implemented. However, because of their importance to the design and the potential impact of resolutions of

policy issues, they are provided to provide the Commission context regarding the affect of applicable policy issue resolutions.

The technical issues affected by the resolutions of the policy issues in this paper include:

- ***Core Composition and Source Term Issues for SMRs***

  Scope: Technology/design-specific
  Importance: High

  As discussed in Section 3.3 of this paper, source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. The source terms for the integral PWRs may be based partly on source-term information from current generation LWRs and insights gained from extensive state-of-the-art fission product experiments conducted to understand accident phenomena including fission product transport and release. In addition, license applicants and the NRC will need to establish appropriate bounding source terms for HTGRs and SFRs and the conditions under which their use can be justified in licensing.

  In SECY-93-0092, the NRC staff proposed that source terms for HTGRs and SFRs should be based upon a bounding mechanistic analysis that meets certain performance and modeling criteria supported by research and test data. The conditions under which the use of design-specific and event-specific mechanistic source terms can be justified and used in licensing non-LWRs will have to be supported by experimental data to confirm the parameters of the source term. In its SRM dated July 30, 1993, the Commission approved the staff's recommendation. The NRC staff will ensure that uncertainties are accounted for in the designs. Because of the implications of using design-specific and event-specific mechanistic source terms in licensing, the technical basis for and the uses of such source terms in licensing are critical to the resolution of this technical issue.

  In addition, differences in the core composition of non-LWRs could result in potential policy issues concerning fuel cycle and transportation impacts, including environmental impacts of the production, transportation, and storage of reactor fuel and radioactive waste for non-LWRs. In SECY-02-0180, the NRC staff recommended that the environmental effects of the production, transportation, and storage of reactor fuel and radioactive waste be reviewed on an application-by-application basis for non-LWR license applicants. The Commission approved the staff's recommendation in its SRM dated March 31, 2003.

- ***Accident Selection for SMRs***

  Scope: Generic (although more germane to non-LWRs)
  Importance: High

  For SMRs, the NRC staff will need to consider a different or revised set of accidents than those considered for current LWRs to provide a basis for selecting a mechanistic siting source term and for judging the adequacy of features such as containment functional design and offsite emergency planning. The NRC staff will need to consider accident scenarios during power ascension, full power operation, power decrease, and low power operations.

In the August 2008 NGNP Licensing Strategy, the Commission stated that licensing-basis event categories (i.e., abnormal occurrences, design-basis accidents, and beyond-design-basis accidents) would be established based on the expected probability of event occurrence. However, selection of licensing basis events within each category would be performed using deterministic engineering judgment complemented by insights from the NGNP PRA. In general, the NRC staff expects to apply this approach to all SMRs.

Although identification of many accident scenarios will likely be straightforward, the application of certain scenarios may require Commission consideration. For example, designers of HTGRs have previously proposed that the failure of the vessel or piping connecting the reactor vessel and steam generator vessel need not be considered as a design basis event. In addition, although the Commission has previously stated that certain events should be addressed for non-LWR designs, subsequent research and evaluations may challenge the need to analyze these low probability events.

- ***Redundancy of the Passive Residual Heat Removal System***

  Scope: Generic
  Importance: High

  In SECY-93-0092, the NRC staff identified an issue regarding whether advanced reactor designs that rely on a single, completely passive, safety-related residual heat removal (RHR) system would be acceptable. The staff stated that the unique features of the PRISM and Modular High-Temperature Gas-Cooled Reactor (MHTGR) designs lead the NRC staff to believe that reliance on such an RHR system may be acceptable, depending on how the designer addresses this issue. In performing its detailed design evaluation, the NRC staff committed to ensure that NRC regulatory treatment of non-safety-related backup RHR systems is consistent with Commission decisions on passive LWR design requirements. In its SRM dated July 30, 1993, the Commission approved the staff's approach. The NRC staff will ensure that treatment of proposed non-safety-related backup systems is adequately addressed in SMR designs.

- ***Classification of Structures, Systems, and Components***

  Scope: Generic (although more germane to non-LWRs)
  Importance: High

  During its reviews of recent LWR design and license applications, the NRC staff has used deterministic judgment, complemented by insights from the design-specific PRA, to review SSCs relied on to prevent or mitigate safety-significant licensing-basis events. In conducting its review, the staff verified that safety margins were adequate to ensure the integrity and performance of safety-significant SSCs using a conservative analysis or a best-estimate analysis with consideration of uncertainties. The NRC staff expects to apply this approach to most of the SMR design reviews. If necessary, special treatment requirements would be established to ensure the required performance capability and reliability of the safety-significant SSCs, using deterministic engineering judgment, complemented by insights and information from the design-specific PRA.

The NRC staff stated that it planned to use this approach to classify the SSCs for the NGNP in the August 2008 NGNP Licensing Strategy. However, as discussed in Section 3.2 of this paper, alternative approaches are being considered that put more emphasis on the use of risk insights that are complemented by deterministic evaluations and engineering judgment. DOE or an SMR designer may propose such an approach to justify modification of the design, installation, and maintenance requirements of the identified safety-related SSCs. Once that policy issue is resolved, the NRC staff will ensure that it is adequately implemented when conducting its design or license reviews.

- ***Containment Functional Capability for SMRs***

Scope: Generic (although more germane to non-LWRs)
Importance: High

Fission product retention during an accident involving an HTGR will be highly dependent upon the ability of its coated fuel particles to maintain their integrity and retain fission products during normal operation and accident conditions. Previous gas-cooled reactor designs have relied on similar coated fuel particle technology and have demonstrated the feasibility of using fuel as the primary barrier to fission product release. SFR designers rely on their fuel characteristics and cladding, the reactor vessel, and a containment system that is expected to be exposed to low pressures during an accident to provide multiple barriers to retain fission products. The IRIS and mPower LWR designs employ more conventional LWR barrier designs, relying on their fuel cladding, the reactor coolant pressure boundary, and containment design to retain fission products, and are not expected to raise policy issues in this area. However, the NuScale LWR design employs a non-traditional, small containment for each module that operates in a large pool of water. This unique design could raise construction and operational issues that must be adequately addressed by the designer.

In SECY-03-0047, the NRC staff recommended that the Commission approve the use of functional performance requirements to establish the acceptability of a containment or confinement structure (i.e., consideration of a non-pressure-retaining building provided certain performance requirements can be met). In developing the requirements for SMRs, the need for and type of containment barrier will have to be established. This will involve taking into consideration factors such as fuel quality and performance, plant transient behavior, security, aircraft impact assessments, and DID.

In an SRM to SECY-03-0047, the Commission disapproved the staff's recommendation related to the requirement for a pressure-retaining containment building, but directed the staff to pursue the development of functional performance standards and then submit options and recommendations to the Commission on this issue. The variety of designs currently being proposed may result in this issue being brought before the Commission for resolution on specific designs or groups of designs.

4.0 Operational Issues for Small Modular Nuclear Reactors

4.1 Appropriate Requirements for Operator Staffing for Small or Multi-Module Facilities

Scope: Generic
Importance: High
Issue Paper: FY 2012

Some SMR designs may use multiple modules at one site, but current regulations do not address the possibility of more than two reactors being controlled from one control room. In SECY-93-0092 and SECY-02-0180, the NRC staff discussed whether advanced reactor designs should be allowed to control more than two reactors from one control room and operate with a staffing complement that is less than that currently required by the Commission's regulations. The NRC staff stated that it believed that operator staffing may be design dependent and intended to review the justification for a smaller crew size for the advanced reactor designs by evaluating the function and task analyses for normal operation and accident management. In SECY-93-0092, the staff identified several factors that could be used in assessing the staffing levels for SMRs, including the following:

- Whether smaller operating crews could respond effectively to a worst-case array of power maneuvers, refueling and maintenance activities, and accident conditions.

- Whether an accident at a single unit could be mitigated with the proposed number of licensed operators, less one, while all other units could be taken to a cold-shutdown condition from a variety of potential operating conditions, including a fire in one unit.

- Whether the units could be safely shut down with eventual progression to a safe shutdown condition under each of the following conditions: (1) a complete loss of computer control capability, (2) a complete station blackout, or (3) a design-basis seismic event.

The NRC staff also concluded that an "actual control room prototype" should be used for test and demonstration purposes. In its SRM dated July 30, 1993, the Commission approved the staff's recommendation. Other potential SMR policy issues include the possible need for requirements on control room staffing during refueling operations, reactor staff who interact with an interconnected manufacturing plant, supervisory staff, shift work, and training.

During pre-application discussions with the NRC staff, SMR designers have indicated that they are evaluating whether the function and task analyses for normal operation and accident management conducted for their SMR designs support control of more than two modules from one control room and support operation with a staffing complement that is less than that currently required by the Commission's regulations. The NRC staff believes that resolution of this issue is required to support the design development, and the staff's review, of design and license applications for most of the SMR designs, including the NGNP. The staff intends to re-assess and revise, as needed, the earlier staff technical positions and plans for resolving the operator staffing issue for SMR designs. Therefore, the issues have been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning operator staffing and associated control room design that

it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with human factors and instrument and controls experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or staff positions or propose new guidance concerning the operator staffing for an SMR in FY 2012 to support development of the NGNP, integral PWRs, or other SMR designs.

4.2 Operational Programs for Small or Multi-Module Facilities

Scope: Design-specific
Importance: Medium
Issue Paper: FY 2013 or beyond

Policy issues may be identified during the development of operational programs such as inservice inspection and inservice testing programs for SMRs. The unique design of safety-related components, such as the helical steam generators in integral PWRs, may present difficulties and restrictions to the capability to thoroughly conduct the required inspections and tests. The introduction of new technologies and design features may require the development of new operational programs that have not been needed for the current-generation large LWRs or the need to significantly modify current operational programs. On-line refueling and the increased time period between refuelings for certain reactors (from 4 to as many as 30 years between refuelings) may introduce policy issues concerning longer time intervals between periodic inspections and tests. Commission input may be required to determine whether the proposals are acceptable from a policy standpoint..

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. However, the staff believes that resolution for this issue need not occur until after a license application is submitted because it concerns activities that will need to be addressed near the end of an operating license review. Once a license application is received, the NRC staff will review the proposed operational programs for the facility, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and determine the acceptability of the applicant's proposed operational programs. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning these operational programs for the facility in a timeframe consistent with the licensing schedule.

4.3 Installation of Reactor Modules During Operation for Multi-Module Facilities

Scope: Design-specific
Importance: High
Issue Paper: FY 2013 or beyond

The multi-module aspect of certain SMR designs allows modules to be added to the facility while modules that were installed earlier are operating. This type of evolution and possible effects on shared systems and structures could raise policy issues requiring Commission consideration before final decisions regarding the acceptability of a design or issuance of a license are made.

This issue is applicable to license applications for certain integral PWRs. However, the staff believes that resolution for this issue need not occur until after a license application is submitted because it concerns activities that will need to be addressed near the end of an operating license review. Once a license application is received, the NRC staff will review the proposed installation scenario for the facility, consider white papers or topical reports concerning this issue that it receives from the SMR applicant, discuss design-specific proposals to address this matter, and determine the acceptability of the applicant's proposed installation proposal. Should it be necessary, the staff will propose resolutions changes to existing regulatory guidance or new guidance concerning this operational program for the facility in a timeframe consistent with the licensing schedule.

4.4 Industrial Facilities Using Nuclear-Generated Process Heat

Scope: Generic
Importance: High
Issue Paper: FY 2013 or beyond

Besides generating electricity, SMRs provide a possible source of process heat for industrial uses because of their size, high heat production, and capability to be located in remote areas. SMRs are being considered for such industrial uses as producing process heat for chemical plants, refineries, desalinization plants, hydrogen production facilities, and bitumen recovery from oil sands.

The NRC staff has identified potential policy and licensing issues for those facilities used to provide process heat for industrial applications. The close coupling of the nuclear and process facilities raises concerns involving interface requirements and regulatory jurisdiction issues. Effects of the reactor on the commercial product of the industrial facility during normal operation must also be considered. For example, tritium could migrate to a hydrogen production facility and become a byproduct component of the hydrogen product. Resolution of these issues will require interfacing with other government agencies and may require Commission input to determine whether the design and ultimate use of the product is acceptable.

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. However, the staff believes that resolution for this issue need not occur until after a license application is submitted because it concerns site-specific issues associated with the staff's review of an operating license. Once a license application is received, the NRC staff will review the how the nuclear facility is connected to the industrial facility, consider the interrelationship between the staffs of both facility, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and review similar activities with nuclear and non-nuclear facilities. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning the effect of the industrial facility on the nuclear facility in a timeframe consistent with the licensing schedule.

4.5 Security and Safeguards Requirements for SMRs

Scope: Generic
Importance: High
Issue Paper: FY 2011

Traditionally, the approach for security to comply with 10 CFR Part 73, "Physical Protection of Plants and Materials," has largely been one of assessing a plant design and overlaying security provisions (e.g., fences, locked doors, guards) on that design. For SMRs, traditional security provisions could be similar to those for current LWRs. Similarly, material control and accounting (MC&A) safeguards requirements for reactors have been limited to the recordkeeping and other related requirements in 10 CFR 74.19, "Recordkeeping." These would be appropriate and applicable for most of the SMRs. However, SMRs with unique fuel handling requirements may require special licensing requirements for MC&A.

However, since September 11, 2001, it has been recognized that a stronger tie between design and security would be useful so as to integrate the resolution of security issues during the design process. Because many SMRs are still in early developmental stages and the designs are not yet fixed, the designers have a unique opportunity to determine the appropriate design basis threat; develop emergency preparedness; and integrate physical security protection, cyber security protection, and MC&A measures with the design and operational requirements during the design process and during the development of a license applicant's physical security and MC&A programs and systems. Therefore, SMR designers are expected to integrate security into the design and will need to conduct a security assessment to evaluate the level of protection provided, including safeguards aspects of SMR-related fuel cycle and transportation activities.

The small size, reduced number of vital areas, and design approaches that incorporate safety systems underground that characterize the SMR designs have led DOE, SMR designers, and potential SMR operators to raise issues regarding the appropriate number of security staff and size of the protected area. The NRC will need to reevaluate the applicability of the appropriate performance and prescriptive regulatory requirements based on a variety of SMR designs, the design specific source terms to cause radiological sabotage, the enrichment and material forms of special nuclear material, and specific SMR design and license applications. These evaluations will likely require either design or site-specific justifications to support proposed relief from established regulatory requirements or consideration by the Commission before final decisions regarding the acceptability of a design or issuance of a license are made.

The NRC staff believes that resolution of this issue is required to support the design development of the NGNP, integral PWRs, and other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning safeguards that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with safeguards experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance

concerning safeguards for an SMR in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.

4.6 Aircraft Impact Assessments for SMRs

Scope: Design-specific
Importance: High
Issue Paper: FY 2012

On June 12, 2009, the Commission promulgated the Aircraft Impact Rule (74 FR 28112), which requires design and license applicants for new nuclear power reactors to perform a rigorous assessment of their designs to identify design features and functional capabilities that could provide additional inherent protection to avoid or mitigate the effects of an aircraft impact. The applicant is required to identify and incorporate into the design those design features and functional capabilities that avoid or mitigate, to the extent practical and with reduced reliance on operator actions, the effects of the aircraft impact on key safety functions. The applicant is required to show that, with reduced operator actions: (1) the reactor core remains cooled, or the containment remains intact; and (2) spent fuel pool cooling or spent fuel pool integrity is maintained. In its Statement of Considerations for rulemaking, the NRC acknowledged that these requirements may not be applicable to non-LWR designs, or may have to be supplemented by other key functions. When reviewing non-LWR designs, the NRC will evaluate the applicability of the acceptance criteria set forth in the aircraft impact rule and the possible need for other criteria. If necessary, the NRC will issue exemptions and impose supplemental criteria in a design certification or license to be used in the aircraft impact assessment for such non-LWR designs.

Aircraft impact assessments may be needed for future small module design reactors. In addition, aircraft impact issues may have to be addressed for industrial facilities that are using nuclear-generated process heat. Proposed resolutions of this issue for an SMR may require Commission input to determine whether the design approach is in keeping with Commission policy on this issue..

The NRC staff believes that resolution of this issue is required to support the design development of the NGNP, integral PWRs, and other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning aircraft impact assessments that it receives from DOE and potential SMR applicants, and discuss design-specific proposals to address this matter. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning aircraft impact assessments for SMRs in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.

4.7 Offsite Emergency Planning Requirements for SMRs

Scope: Generic
Importance: High
Issue Paper: FY 2012 or beyond

In SECY-93-0092, the NRC staff questioned whether applicants for licenses referencing advanced reactors with passive design safety features should be able to adjust emergency planning zones (EPZs) and requirements. The staff proposed no changes to the existing regulations governing emergency planning for advanced reactor licensees, and stated that it would provide regulatory direction at or before the start of the design certification phase so that emergency planning implications on the design can be addressed. In its SRM dated July 30, 1993, the Commission stated that it was premature to reach a conclusion on emergency planning for advanced reactors and directed the NRC staff to use existing regulatory requirements. However, it instructed the staff to remain open to suggestions to simplify the emergency planning requirements for reactors that are designed with greater safety margins.

Consideration of emergency preparedness by SMR developers is an essential element in the NRC's DID philosophy, which provides that, even in the unlikely event of an offsite fission product release, there is reasonable assurance that emergency protective actions can be taken to protect the population around nuclear power plants. However, the smaller size, lower power densities, lower probability of severe accidents, slower accident progression, and smaller offsite consequences per module that characterize SMR designs have led DOE, SMR designers, and potential SMR operators to raise questions regarding the appropriate size of the EPZ, the extent of onsite and offsite emergency planning, and the number of response staff needed. Other topics raised by the industry involve the potential to revise alert and notification requirements and the appropriateness of the protective action requirements in 10 CFR 50.47(b)(10) for SMRs. Although the NRC’s current regulations allow for the review of requirements on a case-by-case basis, the Commission may wish to consider such changes for the many designs for which modification is justified. In addition, the applicants requesting certification of their reactor designs may seek finality by having approved changes in offsite emergency planning included as part of the design certification proceeding. Should the applicants propose deviation from NRC requirements, Commission input may be needed to determine whether the proposals are in keeping with Commission policy on this issue..

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. Although resolution of this issue may have a higher importance to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of this issue may not involve design issues, and therefore, addressing such issues is more appropriate before the COL application stage. A change in the requirements for protective actions and the size of an EPZ is a policy issue that will be of interest to all stakeholders, including the Federal Emergency Management Agency (FEMA) and the public. Any changes to current policies would necessitate appropriate changes to the regulatory requirements and associated guidance documents. This effort would be needed in preparation for COL application reviews. Should it be necessary, the staff will propose changes to existing regulatory requirements and guidance or develop new guidance concerning reduction of offsite emergency preparedness for SMRs in a timeframe consistent with the licensing schedule.

The NRC staff will consider white papers or topical reports proposing to deviate from emergency preparedness requirements that it receives from DOE and potential SMR applicants. During its reviews of COL applications, the staff will discuss site-specific justifications to support proposed deviations, review site-specific proposed emergency preparedness plans, coordinate the reviews with the FEMA, and review similar activities with other nuclear facilities.

5.0 Financial Issues for Small Modular Nuclear Reactors

5.1 Annual Fee for Multi-Module Facilities

Scope: Generic
Importance: Medium
Issue Paper: FY 2011

The 104 power reactors currently licensed to operate have licensed power limits ranging from 1,500 to 3,990 MWt. SMRs are expected to have capacities ranging from 30 to 1,000 MWt. As discussed previously, some of these SMRs may not generate electric power, but instead may be used to generate process heat for industrial applications, such as the production of hydrogen or bitumen recovery from oil sands. Current regulations governing annual fees for power reactors require the same fees from a commercial nuclear reactor designed to produce electrical or heat energy regardless of capacity. SMR developers have identified concerns with this fee structure because of the significant adverse effect on SMR economics.

Although the Commission's regulations allow granting exemptions to the fee requirements if the licensee can justify the reduction in the annual fee, the Commission has issued an advanced notice of proposed rulemaking (ANPR) in March 25, 2009, stating that it is considering whether to amend its regulations to establish a variable annual fee structure for power reactors based on the reactor's licensed power limit contained in operating licenses (including COLs). The ANPR raises issues such as the following:

1. Whether a variable annual fee structure should be based on either the licensed thermal or electric power limits of the power reactor.

2. What the ranges should be for each group or category of reactors if a variable annual fee structure is established.

3. Whether a variable annual fee structure should account for the various configurations made possible by the modular reactors, including single or multiple modules feeding steam to one steam generator or a combination of the application of process heat and electricity production at one facility.

4. Whether and how the fee structure should account for a COL that is issued for a set of modular reactors located at a single site where the licensee can construct, install, and operate each reactor module over a long period of time, depending on the licensee's needs.

The comment period ended on June 8, 2009, and in SECY-09-0137, the NRC staff recommended establishing a working group to analyze options and suggested methodologies

for setting fees for nuclear power reactors, including SMRs. In an SRM dated October 13, 2009, the Commission approved the recommendation. Depending on the working group's recommendation, a proposed amendment to the rule may be presented in a future fee rule.

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. Although resolution of this issue before submittal of a license application may be more important to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of this issue need not occur until after a licensing application is submitted because it concerns activities that will need to be addressed during an operating license review. However, the likely timing for subsequent Commission papers on this issue provided above is based on the effort associated with the ANPR. The NRC staff will review information submitted as part of the ANPR, including white papers concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and determine whether a proposed amendment to the rule is appropriate. Should it be necessary, the staff will propose changes to the Commission's regulations following the process for processing the ANPR.

5.2 Insurance and Liability for SMRs

Scope: Generic
Importance: Medium
Issue Paper: FY 2011

Section 170 of the Atomic Energy Act (known as the "Price-Anderson Act"), establishes an indemnification and public liability scheme for damages resulting from nuclear power reactor accidents. As discussed previously, SMR configurations include the possibility of using the energy produced by the reactor for process heat in industrial processes, with little or no provision for the actual generation of electricity. Under current law, the maximum public liability for accidents involving non-electric generating SMRs would be much lower than that for comparable electric generating nuclear facilities. If an SMR is not designed and constructed to produce electricity in excess of 100,000 electric kilowatts, it may not be required to participate in the retrospective premium pool established by the Price-Anderson Act, and could be subject to a much lower level of public liability than SMRs designed to produce electricity in excess of 100,000 electric kilowatts.

Therefore, legislation amending the Price-Anderson Act may be necessary to treat non-electricity generating SMRs with no rated electrical generation capacity in a comparable fashion to the electric generating nuclear facilities that are subject to the retrospective premium insurance pool. For example, it may be appropriate for Congress to consider the applicability of the retrospective coverage in the Price-Anderson Act to an SMR with a rated capacity of 300,000 thermal kilowatts rather than 100,000 electric kilowatts. This would clarify that SMRs would be subject to the retrospective insurance pool and higher public liability, thus ensuring that these reactors would be treated the same under the Price-Anderson Act as current commercial nuclear power plants, regardless of those reactors' end-use. Section 140.11(a)(4) of the NRC's regulations tracks the Price-Anderson Act's insurance requirements, including the requirement to maintain retrospective premium insurance, for nuclear reactors designed for the production of electrical energy with a rated capacity of at least 100,000 electrical kilowatts. Accordingly, this regulation would not apply to commercial non-electric generating SMRs. The

current financial protection requirements of 10 CFR Part 140, “Financial Protection Requirements and Indemnity Agreements,” for all other types of commercial nuclear reactors would apply to non-electric generating SMRs. This is because financial protection requirements for all other types of commercial reactors are based on "thermal power level" rather than electrical kilowatt capacity. See 10 CFR Sections 140.11 and 140.12. The NRC staff will notify the Commission should it conclude that amendments to the Price-Anderson Act or revisions to its regulations may be appropriate.

In addition, in accordance with 10 CFR 50.54(w), separate insurance coverage is required to cover property damage at the site to ensure that the licensee has sufficient funds to stabilize the facility and clean up the site in the event of a nuclear accident. The amount of on-site property insurance required is the lesser of $1.06 billion or whatever amount of insurance is generally available from private sources. This insurance could be a significant cost for an SMR. The amount of insurance required for an SMR may be an issue requiring Commission consideration.

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. Although resolution of this issue before submittal of a license application may be more important to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of this issue need not occur until after a licensing application is submitted because it concerns activities that will need to be addressed during an operating license review. However, the likely timing for subsequent Commission papers on this issue provided above is based on the need to determine early whether legislation or rulemaking is necessary to address this issue, and how much lead time is necessary to conduct these activities. The NRC staff will consider white papers concerning this issue that it receives from DOE and potential SMR applicants, and determine whether legislation or rulemaking is appropriate to address this issue. Should it be necessary, the staff will propose changes to existing legislation or regulations in a timeframe consistent with the licensing schedule.

5.3 Decommissioning Funding for SMRs

Scope: Generic
Importance: Medium
Issue Paper: FY 2013 or beyond

In SECY-02-0180, the NRC staff questioned whether a non-electric utility may use an alternative method for decommissioning funding for its nuclear power facility, such as partial prepayment. Current NRC regulations allow an applicant several options for funding decommissioning. Non-electric-utility licensees are not allowed to use the sinking fund option exclusively (uniform series of payments). The staff recommended that the NRC require non-electric-utility licensees to use the other options provided in 10 CFR 50.75, “Reporting and Recordkeeping for Decommissioning Planning,” to fund decommissioning costs. At that time, the NRC staff did not recommend that the Commission’s regulations be modified to allow additional alternatives for decommissioning funding. In its SRM dated March 31, 2003, the Commission approved the staff’s recommendation.

In the same Commission paper, the NRC staff questioned whether a non-LWR applicant could submit design-specific decommissioning cost estimates. The minimum amount of

decommissioning funds required of boiling-water reactors and PWRs is regulated through the minimum decommissioning funds equation in 10 CFR 50.75(c). However, there are no formulas specifically for non-LWR designs. Because the regulations allow the use of a site-specific estimate instead of the amount calculated through the generic formula, the staff stated that it would accept a minimum decommissioning cost estimate specifically for the PBMR or for the GT-MHR if the applicant could technically justify the estimate. For a modular facility, the NRC staff stated that the applicant could submit a standard decommissioning cost estimate based on the decommissioning of one module, which can then be applied multiple times for the facility in question, or (alternatively), a cost estimate based on the decommissioning of multiple modules at a single location. Regardless of the method used, the resulting estimate must include the cost of decommissioning common elements and structures associated with the facility, in addition to the costs of decommissioning each individual module. The NRC staff believes that it is appropriate to accept design-specific decommissioning cost estimates for the potential non-LWRs currently under consideration. In addition, it may be appropriate for the integral PWR designers to submit design-specific decommissioning cost estimates provided adequate justification is provided. The NRC will review each design-specific decommissioning cost estimate submitted on an SMR on a case-by-case basis. Issues concerning the decommissioning costs of an SMR may require Commission consideration.

This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. Although resolution of this issue before submittal of a license application may be more important to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of this issue need not occur until after a licensing application is submitted because it concerns activities that will need to be addressed during an operating license review. Once a license application is received, the NRC staff will review the associated design-specific decommissioning cost estimate, consider white papers concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and determine whether the estimate is acceptable in light of current regulations and regulatory guidance. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning decommissioning costs for SMRs in a timeframe consistent with the licensing schedule.

Descriptions of Small Modular Nuclear Reactor Designs

The following are design descriptions of the small modular integral light-water reactor (LWR), high-temperature gas-cooled reactor, and sodium-cooled fast reactor (SFR) designs that have been under development by nuclear reactor designers, who have notified the U.S. Nuclear Regulatory Commission (NRC) that that they may submit design and license applications for some of their designs to the NRC as early as fiscal year (FY) 2011.

Next Generation Nuclear Plant

In Subtitle C of the Energy Policy Act of 2005 (EPAct), Section 641 states that the Secretary of Energy shall establish the Next Generation Nuclear Plant (NGNP) project, which will consist of constructing, licensing, and operating a prototype nuclear plant that can be used to generate electricity, hydrogen, or both. As defined by the EPAct, the NGNP will be a full-scale prototype plant that will be reliable, safe, proliferation resistant, and economical and will demonstrate the commercial potential of the design and associated technologies. Although the prototype NGNP is planned to be a single unit, issues regarding multi-module operation could be applicable to future commercial NGNP applications. The mission of the NGNP includes providing high-temperature process heat for the chemical industry, refining petroleum, extracting oil from shale and tar deposits as an alternative to natural gas, producing hydrogen, and serving as a central electric power station. To meet this mission, the Department of Energy has concluded that the NGNP should be a gas-cooled, very-high-temperature reactor, and could be considering designs such as the Pebble Bed Modular Reactor (PBMR), the Gas-Turbine Modular Helium Reactor (GT-MHR), and AREVA's New Technology Advanced Reactor Energy System (ANTARES). These designs have the potential to produce the high-temperature heat needed to support the mission of the NGNP while relying on inherent characteristics and passive safety features to mitigate design-basis accidents (DBAs). The following describes each of these designs:

- **Pebble Bed Modular Reactor**

  The Pebble Bed Modular Reactor (PBMR) is a 400 megawatt-thermal (MWt) modular high-temperature helium-cooled reactor under development by PBMR (Pty.) Ltd. Its baseline configuration is for use as an electric power plant with a power output ranging from 165 megawatt-electric (MWe) (i.e., one reactor module) to 1320 MWe (i.e., eight reactor modules). The PBMR module consists of a graphite-moderated, helium-cooled reactor and a direct closed-cycle turbine-driven generator. The 450,000 fuel pebbles that comprise the core are billiard-ball-sized graphitic spheres containing fuel kernels composed of low-enriched (9 percent) uranium dioxide (UO_2) coated with a fission-product-retaining tri-structural isotropic (TRISO) coating. The PBMR reactor core and fuel are based on the high-temperature gas-cooled reactor technology that was originally developed in Germany.

- **Gas-Turbine Modular Helium Reactor**

  The Gas-Turbine Modular Helium Reactor (GT-MHR) is a 600 MWt (285 MWe) modular high-temperature helium-cooled reactor (MHTGR) under development by General Atomics that consists of a graphite-moderated, helium-cooled reactor and a direct closed-cycle turbine-driven generator. The fuel is in the form of graphitic cylindrical fuel compacts containing fuel kernels composed of low-enriched (10 – 19.9 percent) UCO coated with a fission-product-retaining TRISO coating. The fuel compacts are inserted into hexagonal prismatic graphite blocks. The GT-MHR design is based on the Fort St. Vrain, and later MHTGR, designs developed by General Atomics.

- **AREVA's New Technology Advanced Reactor Energy System**

  The AREVA's New Technology Advanced Reactor Energy System (ANTARES) is a 600 MWt (285 MWe) modular high-temperature helium-cooled reactor under development by AREVA that consists of a graphite-moderated, helium-cooled reactor and indirect-cycle gas- and steam-turbines using intermediate heat exchangers. The fuel is in the form of graphitic cylindrical fuel compacts containing fuel kernels composed of low-enriched (10 – 19.9 percent) UO_2 coated with a fission-product-retaining TRISO coating. The fuel compacts are inserted into hexagonal prismatic graphite blocks.

Super-Safe, Small and Simple Reactor

The Super-Safe, Small and Simple Reactor (4S) reactor is a small, 30 MWt (10 MWe) pool-type SFR, designed by the Toshiba Corporation, that is intended for use in remote locations where it could operate for up to 30-years without the need for refueling. The 4S reactor is designed to rely on inherent safety characteristics and passive features to achieve all safety functions for all licensing basis events. The reference 4S reactor design produces 10 MWe, although both larger and smaller 4S reactor designs are also proposed. Fuel inside steel-clad rods is composed of a uranium-zirconium alloy at enrichments of 17 and 19 percent U-235. For deployment in the United States, the major components of the 4S reactor, including the fuel and reactor vessel, would be fabricated at a factory, shipped to the intended site, and assembled and installed underground in a below-grade civil structure.

Power Reactor Inherently Safe Module

The Power Reactor Inherently Safe Module (PRISM) reactor is a modular, pool-type SFR design first developed by the General Electric Company. The standard plant design for the PRISM consists of three identical power blocks with a total electrical output rating of 1395 MWe. Each power block comprises three reactor modules, each with an individual thermal rating of 471 MWt (155 MWe). Each module is located in its own below-grade silo and is connected to its own intermediate heat transport system and steam generator system. The reactor core consists of a metallic-type fuel rod composed of a ternary alloy of uranium-plutonium-zirconium clad in steel. The design includes passive reactor shutdown and passive decay heat removal features.

International Reactor Innovative and Secure

The International Reactor Innovative and Secure (IRIS) is a 1000 MWt (about 335 MWe) modular pressurized-water reactor (PWR) design with an integral configuration, under development by an international consortium of more than 30 organizations from nine countries, led by Westinghouse Electric Company. All primary system components (pumps, steam generators, pressurizer, and control rod drive mechanisms) are inside the reactor vessel. The reactor uses traditional PWR fuel rods (less than 5-percent enrichment) arrayed in 17x17 fuel bundles. A power station could be built with one or more modules. IRIS has an extended core life of up to 48 months. IRIS is designed to rely on passive safety features to mitigate design basis accidents. Its design for electric power generation has progressed to the integrated testing phase, and it is currently in the final design and development phase.

NuScale Power Reactor

The NuScale Power Reactor is a 150 MWt (45 MWe) natural circulation PWR design that consists of a self-contained assembly with the reactor core and steam generators located in a common reactor vessel. The reactor uses approximately one-half-height PWR fuel rods (less than 5-percent enrichment) arrayed in 17x17 bundles. The NuScale light-water reactor design employs a non-traditional, small containment for each module that operates in a common, large pool of water. Electrical power conversion involves the use of steam generators and a steam turbine-generator. NuScale Power, Inc., plans to submit a design certification application for a 12-module facility. These modular units would be manufactured at a single centralized facility; transported by rail, road, and/or ship; and installed as a series of self-contained units, each with a 24-month refueling cycle. The design is being developed by NuScale Power, Inc.

mPower Reactor

The mPower Reactor is a 400 MWt (125 MWe) PWR module that consists of a self-contained assembly with the reactor core, reactor coolant pumps, and steam generators located in the reactor vessel. The mPower reactor, under development by the Babcock & Wilcox Company, employs control rods but no soluble boron for normal reactivity control. The reactor uses approximately one-half-height PWR fuel rods (less than 5-percent enrichment) arrayed in 17x17 bundles. The reactor module uses a once-through steam generator and plans on a 5-year fuel cycle. The designer is still in the process of determining whether two modules will feed one turbine-generator through a common steam header to produce a total of 250 MWe.

Key Documents Concerning Policy, Licensing, and Key Technical Issues For Small Modular Reactors[4]

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