April 9, 1992

Docket No. 52-002

Mr. E. H. Kennedy, Manager
Nuclear Systems Licensing
Combustion Engineering
1000 Prospect Hill Road
Windsor, Connecticut 06095

Dear Mr. Kennedy:

SUBJECT: SEVERE ACCIDENT DESIGN FEATURES

The format and content of the Combustion Engineering Standard Safety Analysis Report - Design Certification (CESSAR-DC) was based on Regulatory Guide 1.70 (RG 1.70, Rev. 3), Standard Format and Content for Safety Analysis Reports for Nuclear Power Plants. Severe accident and design features for their prevention and mitigation are not included in the scope of this latest revision of RG 1.70. The Standard Review Plan (NUREG-0800) also does not include the issues of severe accidents, i.e., accidents worse than design basis accidents. Therefore, the material needed for the Nuclear Regulatory Commission staff closure of these issues may be difficult to locate in the CESSAR-DC or may not have been provided. The enclosed request for information (RAI) (Enclosure 1) and description of the safety evaluation report (SER) (Enclosure 2) are provided to assist the staff in reaching closure on these issues. If this information is currently available, please respond in a time frame to enable the staff to meet its schedule for the draft safety evaluation report. If the information must be developed, please provide a schedule.

Sincerely,

Original Signed By:

Thomas V. Wambach, Project Manager
Standardization Project Directorate
Division of Advanced Reactors
and Special Projects
Office of Nuclear Reactor Regulation

Enclosures:
1. RAI
2. Description of SER

cc w/enclosures:
See next page

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Enclosure 1

REQUEST FOR ADDITIONAL INFORMATION
ON THE DC APPLICATION FOR THE ABB-COMBUSTION
ENGINEERING SYSTEM 80+ DESIGN
DOCKET NO. 52-002
CESSAR-DC SEVERE ACCIDENTS

410.140 Enclosure 2 provides an outline on Severe Accident closure issues which expands on the guidance provided in SECY-90-016. The staff will use this outline in the review of Advanced Light Water Reactor (ALWR) Severe Accident Issues closure. Since this document represents the staff's opinion as to what issues should be addressed for closure of the severe accident issues, show where each of the line items are discussed in the CESSAR-DC. If not currently available, provide a schedule for when the information will be provided to the staff.

EQUIPMENT SURVIVABILITY

410.141 Your response to RAI 440.20 lists, in part, the hydrogen mitigation system igniters and cabling, as well as valves for the reactor cavity floodi ystem, as equipment that is relied upon to mitigate consequen of severe accidents. SECY-90-016 requires that there be high confidence that this equipment will survive severe accident conditions for the period that is needed to perform its intended function. However, SECY-90-016 has concluded that it is not necessary for redundant trains to be qualified to meet this goal.

With this general background, there are several areas where information is missing in your response to I 440.20. Therefore, please provide the following:

a. Provide the results of the calculations used to establish the environmental conditions for severe accident mitigative equipment. These conditions should include pressure, temperature, and radiation, as a function of time. In addition, provide the basis for concluding that the above conditions are bounding for the range of severe accidents.

b. In addition to the environmental conditions, provide any further criteria that will be imposed on the mitigative equipment. Indicate if these added criteria are to justify that there is reasonable assurance that this equipment will perform its function. Provide and justify the seismic design of this equipment.

c. Describe the electric power supplies for post accident mitigative equipment, including train and bus configurations supplying class 1E and alternate power sources. Describe the provisions for switching between the power sources, if required in the course of a severe accident.

SOURCE TERM

410.142 Describe any systems or methods such as on-line monitoring that will be utilized to ensure that the containment leakage rate is maintained below the value assumed.

HYDROGEN GENERATION AND CONTROL

410.143 RAIs 722.13 AND 720.7(b) requested a description of the location of the hydrogen igniters. In addition to this information, provide the separation distance between igniters and a general discussion of where the igniters will be located. For example, how were the various areas considered in the placement of igniters; under overhangs, in all compartments, on the ceiling, and at the source of possible hydrogen? If there is a particular separation distance between igniters, please provide the associated analytical input parameters that were used in conjunction with this value?

410.144 How many igniter assemblies will be allowed in an igniter circuit, and how many are allowed to be inoperable before the Hydrogen Mitigation System is declared inoperable? Also, would inoperable igniter assemblies be allowed to be adjacent to one another and if complete loss of igniters in a compartment will be allowed? Provide the justification for this type of multiple failure criteria.

HIGH PRESSURE CORE MELT EJECTION

410.145 Please identify all CE 80+ design features which prevent core melt or provide a recovery capability.

a. Describe how in the design process these features were selected.

b. Provide some quantification of each features risk benefit worth.

c. Identify which of these features came from existing designs, and which were new or possess new capabilities.

d. Describe the process used to decide which severe accident enhancements should be incorporated into the CE 80+ and which to exclude (if any).

CORE/CONCRETE INTERACTION - CORE DEBRIS COOLABILITY

410.146 In addition to the reactor cavity drawings requested via RAI 722.1, provide the following:

a. Provide the following design details:
   - location and size of any ledge-like surfaces,
   - location and configuration of all penetrations,
   - location and configuration of all openings to the drywell compartment, and
   - size, elevation, and configuration of floor vents; and

b. Identify and provide the results of any experimental tests that support the design of the reactor cavity. Show to what degree the results demonstrate the design objective of the cavity to retain corium debris.

410.147 Describe the methodology used to determine ex-vessel corium debris coolability.

a. Discuss the basis for the methodology used.

b. Include initial conditions, assumptions, results, and conclusions.

c. Quantify and describe the basis for the mass composition and temperature assumed of the debris in the lower head at the time of lower head failure.

d. Please provide the analysis used to determine the amount of debris ejected from the reactor vessel.

e. Please provide the depth of erosion into both the basemat and the reactor vessel pedestals for at least the first 24 hours or until the debris was quenched, whichever came first.

f. What is the maximum penetration that can be tolerated into the pedestals, such that their structural integrity is maintained?

g. Please provide the basis (i.e., calculations, assumptions, and test data) for the penetration rate used in the analysis.

h. What total thickness was assumed for the basemat?

i. Please provide the supporting containment pressure temperature response profile.

j. Please provide a plot of the integrated and instantaneous production rate of non-condensible gases as a function of time.

k. How does the core debris cooling rate affect containment integrity, and what is the maximum time that the containment can withstand with no core debris cooling before integrity is breached?

410.148 Appendix B, Section 9.2.2.7 entitled, "Top Event 5: Late Containment Failure," includes a scenario in which containment spray is unavailable for 24 hours. MAAP Code analyses have apparently shown that for these sequences where the cavity is initially flooded with no containment heat removal capability, it takes longer than 48 hours to overpressurize the CE 80+ containment. Please provide the supporting analysis or bas.. for this 48 hours, including all initial conditions and assumptions used.

410.149 Please provide the consequences of a high-pressure core melt ejection accident (via the MAAP Code) assuming no ingression of coolant into the mass of debris--i.e., assuming the corium is not in a coolable geomentry. Please include the following:

a. a discussion of the phenomenon of ingression into molten core debris as it is cooled,

b. the basis for the assumption used in the CESSAR-DC with regard to ingression into the debris,

c. the expected location of maximum heat generation in the debris bed (Is it at the base and center of the debris bed?),

d. a description of the corium-concrete interaction and its consequences at this location,

e. the earliest projected containment failure under this scenario, and

f. a profile of the thermal effects on the cavity floor for up to 48 hours following vessel failure under this scenario.

410.150 In Section 9.2.2 entitled, "Quantification of the Containment Event Tree Top Events," it is repeatedly stated that if the vessel fails at high pressure, the corium will be widely distributed through containment.

a. Please provide the basis for the assumption that corium debris would be widely distributed (please include test references, if applicable).

b. Could the corium be blown into one location in one mass?

c. Which assumption--the concentrated heat generation of one softened mass or the wide dispersal of fine fragments--would be more conservative?

410.151 A series of ACE/MACE tests are underway at Argonne National Laboratory to demonstrate core debris coolability. Several of these tests have been completed. Discuss the applicability of these tests to the CE 80+ design. Include a discussion on the applicability of the test parameters, assumptions, and results.

410.152 Section 6.3.15 entitled, "Cavity Flooding System," says the flooder valves in the system will undergo a surveillance every refueling outage.

a. Please explain the recommended surveillance for these valves.

b. Is it recommended that these flooder valves be tested (stroked) periodically?

c. Are these valves expected to have a reliability value higher than normal isolation valves? If so, what is the value?

410.153 Is there a consistent thickness throughout containment of at least 3 feet of concrete to protect the steel containment liner?

410.154 Please explain how the containment system can accommodate the following challenges resulting from the thermal decomposition of concrete by molten corium:

a. the degradation of containment cooling and of cleanup capability due to aerosol formation,

b. slow overpressurization resulting from the evolution of noncondensible gases,

c. functional degradation of structural concrete by erosion, including basemat penetration, and

d. combustion of carbon monoxide.

410.155 Describe how the above challenges could affect equipment required for containment cooling and atmospheric cleanup, if they could result in leakage that exceeds the rate specified in General Design Criteria 16, and whether they could result in release through the basemat following the onset of the corium-concrete interaction.

CONTAINMENT BYPASS

410.156 In Section 9.2.1.1.1, two accidents--interfacing system loss of coolant accident (ISLOCA) and steam generator tube rupture (SGTR)--are discussed in relation to containment bypass; i.e., the release of reactor coolant outside containment. Briefly describe all accident sequences that could result in containment bypass, and explain why the releases resulting from these other events are not significant.

NOTE: SGTR events should include failure due to hot containment gases and core debris.

410.157 Please provide drawings for potential containment bypass release paths, and include detailed physical descriptions of the points of release, including dimensions.

410.158 Following a SGTR severe accident with a coincident loss-of-offsite-power, reactor coolant could be released outside containment via main steam safety valves (MSSVs) that do not reseat or via a stuck-open atmospheric dump valve (ADV)--particularly if the steam generator overfills. For this sequence, please provide the following:

a. the worst-case release scenario with conservative assumptions (dispersion factor, iodine spiking, X/Q, fuel failures, end-of-cycle coolant activity, release beginning at time zero, or coincident with the initial SG pressure spike, etc.),

b. a description of any design features, not employed in licensed CE-designed PWRs, that limit or help mitigate the consequences of this scenario, and

c. the risk assessment of the above scenario.

410.159 The CE 80+ design includes MSSVs that vent directly to the atmosphere.

a. In light of recent operating experience showing a significant trend of challenge to steam generator tube integrity, and in light of recent PRA studies indicating that containment bypass represents a significant risk contributor, has consideration been given to diverting the release path through the MSSVs back to containment? If so, please discuss the advantages and disadvantages of such a design.

b. Has consideration been given to upgrading the design pressure of the secondary system (including the MSSVs) to 1500 psi to minimize containment bypass and release to the environment? Please explain.

c. Recent experience and testing indicate that safety valves designed for steam passage tend to fail to reseat after fluid is passed by the seat. Are the MSSVs employed by the CE 80+ design, designed for water passage? If so, how are the MSSVs expected to respond in a steam generator overfill scenario?

d. What is the risk associated with exceeding the radiological release limits in Part 100 during a steam generator overfill scenario?

410.160 During a SGTR, isolation is normally achieved early in the event by isolating the associated main steam isolation valve (MSIV) following the identification of the faulted steam generator.

a. Again, in light of recent operating experience showing a significant trend of challenge to steam generator tube integrity; and in light of recent PRA studies which indicate that bypass represents a significant risk contributor; has consideration been given to minimizing the likelihood of containment bypass during a severe accident with tube ruptures in both steam generators, and to improving main steam line isolation reliability, with a second MSIV? Please discuss the advantages and disadvantages of this redundant isolation capability. If such an upgrade has not been considered, why not? Please explain.

b. What is the risk associated with a SGTR scenario resulting in containment bypass due to failure to isolate the main steam line?

c. Are the MSIVs designed at or above primary system pressure?

CONTAINMENT VENTING

410.161 In SECY paper 90-016, in the "Containment Performance" section, the staff position indicates that a containment design may utilize controlled elevated venting, diverse containment heat removal systems, or may rely on the restoration of normal heat removal systems if sufficient time is available for major recovery actions...for example, 48 hours. CE appears to take credit for the SECY paper "example" of 48 hours, even though this time period is not applicable to the CE 80+ design. For instance, in Section 4.8.2.1.8 of Appendix B, containment failure is projected in approximately 41 hours. Please clarify this inconsistency.

410.162 Did CE consider providing containment (filtered?) vents for containment overpressure protection?

CONTAINMENT PERFORMANCE

410.163 In accordance with SECY-90-016, the design pressure used for severe accident analysis may be calculated one of two ways-- either applying a conditional containment failure probability (CCFP) guideline of 0.1, or using a deterministic method (based on the ASME schedule) offering comparable protection. Therefore, please provide the following:

a. the pressure used for CE 80+ severe accident analysis,

b. the method used to arrive at that pressure (i.e., Service Level C),

c. the rationale for using the above method, and

d. a description of the use of uncertainties in the analysis.

PUBLIC SAFETY GOALS (Severe Accident Mitigation)

410.164 Please provide the analyses that support those design features necessary to mitigate severe accidents. Include initial conditions, assumptions, results, and conclusions. Also identify which design objectives are supported solely by analysis (i.e., having little or no historical or experimental basis).

DESCRIPTION OF SAFETY EVALUATION REPORT FOR CLOSURE OF ISSUES FOR SEVERE ACCIDENTS

BACKGROUND AND OVERVIEW

This section is intended to establish the general guidance or criteria used to evaluate the acceptability of the power plant design to reduce the likelihood and to mitigate Severe Accidents. There are several key documents which provided the bulk of the guidance. They are the Commission's policy statement on severe accident, Part 52 to 10 CFR, and SECY-90-016. It is the intention to provide a discussion which describes the overall approach and mention how each of the above sources was used in the development of the approach.

DEFENSE IN DEPTH PHILOSOPHY

The discussion will address the Commission philosophy of defense in depth and the logic of providing independent barriers. The four major barriers are generally considered to be the fuel clad, the reactor system, the containment, and the site boundary. Each of these barriers provide a measure of protection to the public and are totally independent of each other. In other words, there is no mechanistic tie among them. This concept assures that a failure to understand the sequence associated with one of the barriers will not reduce the effectiveness of the other barriers.

This concept of licensing will be discussed in connection with the guidance provided in the various documents and demonstrate how this defense in depth strategy has been maintained in the evaluation of severe accidents. As part of this discussion, the level of uncertainties associated with severe accidents will be identified and how this uncertainty is treated in the evaluation. This is an important concept since there is a significant increase in the level of uncertainty when one goes from design basis to severe accident space. In addition, uncertainty must be recognized as a consideration when one determines whether the safety goals have been met.

BALANCE BETWEEN PREVENTION AND MITIGATION

A complete consideration of the plant design's severe accident capabilities would include discussion of both design elements which reduce the likelihood of core damage, and features which provide accident mitigation given that a degraded core event occurs. In the areas of accident prevention, design features which the vendor has incorporated into the plant which provide enhanced or alternate means of maintaining core decay heat removal will be discussed. Other design enhancements which reduce potentially significant severe accident initiators shall also be discussed, such as alternate AC sources to reduce station blackout. The important role of the depressurization system to provide for alternate low pressure makeup schemes and to preclude containment challenges (a mitigation feature) will also be discussed. The containment performance aspects of the mitigation role in severe accident treatment will be discussed in more detail in the following sections below.

CONTAINMENT PERFORMANCE GOALS

The need to have certain containment performance goals will be discussed in this section. Guidance provided in SECY-90-016 will be relayed upon to establish the acceptable approaches. Basically two approaches have been approved by the Commission as ways to demonstrate that the containment design has met the safety goals. They are the probabilistic and deterministic methods. The discussion of these two approaches will rely heavily on the guidance provided in SECY-90-016.

In addition to the references to SECY-90-016, a discussion will be provided which updates the material obtained in the SECY paper. In particular, recent findings relative to the short comings of the probabilistic approach will be identified.

SEVERE ACCIDENT PHENOMENOLOGY

This section will provide a brief description of the most important severe accident phenomena, along with an evaluation based on the currently available understanding of the physics involved and existing uncertainties. The discussion should include a description of the events along with a profile of the postulated environment that is envisioned to occur during the course of the event. This section could be thought of as the source of information used to define the events described in the previous sections. The phenomena of interest should include as a minimum:

HYDROGEN GENERATION AND CONTROL

CORIUM-CONCRETE INTERACTION

CORE DEBRIS COOLABILITY

HIGH PRESSURE CORE MELT EJECTION

FUEL COOLANT INTERACTION

MELT ATTACK ON CONTAINMENT STRUCTURE

CONTAINMENT BYPASS

NOTE: This s .tion may not be appropriate place to discuss containment bypass. It is an event, not phenomena!

DISTINCTION BETWEEN SEVERE ACCIDENTS AND DBAs

The purpose of this section will be to clearly identify the differences between how one views the criteria and requirements of current DBAs and severe accident conditions. Specific examples will include a discussion of the acceptable use of best estimate analyses for severe accidents while conservative models are more appropriate for DBAs. From the point of view of what is sufficient to demonstrate that equipment is functional, testing has been viewed as the only acceptable method for DBA conditions. However, for severe accident conditions, some combination of test and analysis may be sufficient. The acceptability of the approach will be made on a case by case basis.

Another example of the differences will be the use of non-safety equipment. Due to the low probabilities of the severe events, it is appropriate to allow the use of non-safety equipment. However, the reliability and availability will be evaluated closely. This review will include a discussion of the specific programs and surveillance that have been committed to by the vendor. These commitments will play a key determining factor in the acceptability of this equipment.

The justification of all of the above differences will be first and foremost the low probabilities of the severe accident events. As a result, there is a basis for relaxing the very rigid requirements of a DBA event. However, the case must still be made that with the relaxed criteria there remains reasonable assurance that the equipment relied upon for the accident analysis will function as required.

CONTAINMENT PHILOSOPHY RELATIVE TO EARLY FAILURES

ACCIDENT SEQUENCES/CONTAINMENT CAPABILITY

An important element of this closure chapter will be an understanding of the various severe accident events. The first step in this process is an identification of the various challenges to the containment. To obtain these events, one should begin with a study of the Containment Event Trees developed for the supporting PRA. From this evaluation, a list of the various plant damage states and related events should be developed. This list should not be limited to power operation but, should also include shutdown operation. Of particular interest are the bypass events. Bypass can be either of the pool or the containment. In either case, the potential release from the containment boundary would not have the benefit of pool scrubbing. Therefore, the release would be unfiltered.

For each sequence, a description of the event should be provided along with the equipment and instrumentation that would be needed to monitor, accommodate, eliminate, or mitigate the event. If design provisions or actions are available which could significantly reduce the frequency of (or eliminate) the event as a risk contributor and they were not implemented, a rationale should be provided as to why they were not accepted.

PRA CONSIDERATIONS

The objective of this section is to provide a general overview of the results of the PRA analysis as they effect containment performance. The detailed discussion is expected to remain in Chapter 19. However for purposes of continuity of the severe accident effort, a brief discussion is necessary within this closure report with particular focus on sequences for which core damage is not arrested in-vessel, and containment failure modes and severe accident phenomena important to risk. The contents should characterize the limitations of the analytical models so as to better understand any limitations of the PRA results. With respect to the results, the uncertainty and sensitivity analyses should be discussed.

EXPERIENCE AND RESEARCH INSIGHTS

This section is intended to present an overview of the existing experience with the various containment subsystems, as well as a status of research (performed and/or ongoing) efforts regarding containment integrity, including both experimental and analytical work. For each of the containment or primary systems considered to either eliminate or mitigate an event, a discussion of the operating experience accumulated to date should be provided. The objective would be to provide some insight into whether or not the system is based on proven technology or to identify those areas that could be considered as advanced in nature. Included in this area, would be the identification of any components whose reliability/availability value used in the PRA is substantially greater than existing data would permit.

Research and testing insights are meant to bridge the gap between the discussion contained in SECY-90-016 and the present. Since this document is more than two years old, the intent of the section is to provide an update on the various research programs that are applicable to the plant design. For example, there nave been several tests performed as part of the ACE/MACE programs. The results of these tests as they pertain to the plant design should be discussed as well as the justification which supports the plant design. Where appropriate, analytical models and their results would be discussed within this section along with the rationale of how these analytical efforts are integrated with the experimental data base. Of particular note would be the identification of any programs that are underway but are not yet completed. These programs should be discussed in light of the licensing schedule.

Finally, this section should end with a series of conclusions relative to how the plant design is supported via testing and analytical studies. This summary should clearly identify any areas that are solely based on analytical results and indicate why supporting test data are not necessary.

FEATURES TO PREVENT AND MITIGATE SEVERE ACCIDENTS

This section is aimed at describing those features which were identified within the PRA that either prevent core damage, prevented an accident sequence from releasing a significant source term from containment or mitigated the consequences of the event. Of particular interest are those features which were added to the design as a result of the initial PRA analyses. If a weakness was identified as a significant risk contributor (either preventive or mitigative), design changes may have been implemented to eliminate this weakness. On the other hand, the weakness may have been shown to not represent a significant and therefore not merit any further consideration. In other words, it is an opportunity to document the value of having a PRA early in the design of both the reactor coolant system as well as the containment. To accomplish this objective, the PRA in conjunction with the Containment Event Trees will be considered. From them, with support from the vendor, the various design features would be extracted to form the basis for the section. The key features of the section are envisioned to include the following features.

A LIST OF DESIGN FEATURES

For each feature, an overview of the RCS and containment conditions during the postulated spectrum of severe accidents or severe accident precursors should be presented along with a discussion of when and how the feature will either prevent core damage, eliminate or mitigate the consequences of the event. In addition, a discussion of how the component or system was added to the design should be provided. For example, it may be a component used in existing designs or it may be a device added to the plant or enhanced as a result of early PRA results. Understanding how the design was influenced by considering severe accidents is an important aspect of any advanced design concept.

EFFECTIVENESS OF EACH FEATURE

One of the most important issues of the severe accident activities is the question of equipment survivability to assure that components remain functional as identified in the PRA. The basic question is whether equipment will survive post-accident conditions to be able to function the way it is intended. An important part of this section will be a discussion of the "envelope" of severe accident conditions and the philosophy of testing vs analysis as a means of demonstrating equipment qualification. Such considerations as the overall importance of the piece of equipment under review, the timing of the function, and the complexity of the function may all play a role into developing the program necessary to adequately demonstrate the level of desired operability. The depressurization system functionality and reliability are also issues which require treatment. The depressurization system not only allows for a low pressure injection success path, but for those sequences where no RCS makeup is available, provides primary system depressurization prior to vessel failure, precluding DCH containment challenge.

OVER PRESSURE PROTECTION OR VENTING SYSTEM

It is our understanding that the present CE System 80+ design does not include over pressure protection or a venting system. If such systems were to be included this section will provide a detailed discussion of the role the over pressure protection system is expected to play in dealing with the severe accident matrix. To begin the discussion, a description of each of the components should be provided along with the design criteria for the components. For example, the question of seismic design of both the piping and supports should be discussed.

Along with this discussion would be a description of how the system is intended to function. In particular, for each sequence, an indication of whether or not the system is needed to satisfy any safety goals should be clearly stated. If it is not needed to satisfy a safety goal, a clear statement as to why the system has been incorporated into the design should be made.

Relative to the operation of the system, the discussion should include the expected release points and the basis upon which one can conclude that the system will not fail for the severe accident environmental conditions associated with the event in question. If operator action is necessary for any sequence, the sequence should be identified and the information that would be used by the operator in taking the action should be discussed.

ACCIDENT MANAGEMENT

This section will address accident management (AM) concept as an extension of the defense-in-depth philosophy. AM will be presented as a coordinated enhancement of several key elements which contribute to the capability to prevent and mitigate severe accidents and minimize their consequences. These elements are identified in SECY-89-012, and include emergency procedures (and supplementary accident management procedures and guidelines now under development by the NSSS vendors as part of the US industry AM program); severe accident training for operators, technical support staff, and utility managers; and instrumentation and information needs for diagnosing and responding to severe accidents.

The review will include an assessment of the following areas:

1. Aspects or features of the plant design which: (1) either alleviate the need for or facilitate the implementation of accident management measures, or (2) require further assessment by the vendor or the utility as part of developing an accident management plan. This will include assessment of planned strategies for dealing with potential severe accidents, use of PRA by the vendor to identify and assess potential strategies, and any plans or commitments to expand the scope of the PRA for this purpose.

2. The vendor's planned approach for assuring that each of the five elements of accident management defined in SECY-89-012 will be appropriately addressed by the vendor or licensee in developing the plant-specific accident management plan for the plant. This will include consideration of the identified responsibilities of the vendor and the licensee for addressing each of the elements, and any methods and/or guidance that are expected to be used in this process.