17 Technical Approach for Integrated Site Risk Analysis Task

The objective of the Integrated Site Risk Analysis (ISRA) task is to estimate the total site risk and to identify the important contributors to the total site risk. In this project, the phrase “total site risk” means the risk due to accidents that affect one or more of the radiological sources located at the site (the Unit 1 reactor, the Unit 2 reactor, the Unit 1 spent fuel pool, the Unit 2 spent fuel pool, and the dry cask storage facility). Earlier project stages will estimate the risk and identify its contributors from accidents that only affect a single radiological source; as a result, the ISRA task will focus on the risk due to accidents that affect combinations of the onsite radiological sources.

Consistent with the overall project objectives, the results of the ISRA task are expected to provide new insights to enhance regulatory decisionmaking and to help focus limited agency resources on issues most directly related to the agency’s mission to protect public health and safety.

17.1 Assumptions and Limitations

1. Multi-source accident sequences can be formed by combining sequences from the single-source PRA models. This assumption implies:

    a. The set of single-source initiating events and sequences is complete. As a result, no additional initiating events or single-source accident sequences need to be defined within the ISRA task.

    b. Site configurations can be formed by superimposing the operating configurations defined within each single-source PRA model, with adjustments as necessary to account for logically impossible combinations or combinations prohibited by Technical Specifications.

    c. Site radiological release states (RRSs) can be formed by combining the RRSs defined within the single-source PRA models, with adjustments as necessary to account for differences in release timing.

2. The ISRA task will focus on identifying and analyzing risk-significant multi-source risk contributors. As a result:

    a. The ISRA task will emphasize analysis breadth (initially considering all possible multi-source accident sequences and consequences, and then using various screening and scoping approaches to identify and focus on risk-significant multi-source sequences). In order to complete the ISRA task within the project’s schedule and budget constraints, simplified PRA logic structures will be used to limit the level of detail within a given multi-source accident sequence.

    b. The screening and scoping approaches used to focus on risk-significant multi-source sequences need to consider both sequence frequency and sequence consequence.

    c. For the purposes of screening and prioritization, the consequences of a multi-source accident can be estimated by summing the consequences of each source that contributes to the multi-source accident.

3. The ISRA task is a highly iterative effort, where intermediate results may be used to refine previously completed steps. The use of iteration is not unique to the ISRA task, but rather reflects the fact that PRA of single sources has always involved iteration among the various analysis steps. Moreover, in order to achieve the overall project schedule, the ISRA task will begin before the single-source PRAs have been finalized, thus introducing the possibility of rework within the ISRA task due to revisions in the single-source PRA models. The need to use iteration within the ISRA task must be carefully managed to ensure the dependencies are adequately included in the model and sufficient level of detail is included to produce useful insights.

17.2 Inputs

1. Single-source PRA models and their results, assumptions, limitations, and descriptions of analysis steps.
2. Final Safety Analysis Report
3. Site maps
4. General arrangement drawings
5. Process and instrumentation drawings (P&IDs)
6. System descriptions
7. Plant operating procedures (e.g., emergency operating procedures, severe accident management guidelines, emergency management guidelines, etc.)

17.3 Analysis Tasks

The Integrated Site Risk Analysis (ISRA) consists of 18 interrelated tasks:

Overall Tasks
Task 1 – Identify individual risk model insights
Task 2 – Develop site risk model selection criteria and assumptions

Level 1 PRA Tasks
Task 1-1 – Identify and prioritize initiating events and accident sequence combinations
Task 1-2 – Identify different site configurations
Task 1-3 – Identify dependencies and common causes
Task 1-4 – Develop simplified event trees
Task 1-5 – Develop simplified fault trees
Task 1-6 – Quantify accident sequence event trees

Level 2 PRA Tasks
Task 2-1 – Identify dependencies and common causes
Task 2-2 – Identify and prioritize site damage states
Task 2-3 – Develop simplified release event trees
Task 2-4 – Develop simplified fault trees
Task 2-5 – Quantify release event trees

Level 3 PRA Tasks
Task 3-1 – Identify dependencies and common causes

Task 3-2 – Identify and prioritize radiological release states
Task 3-3 – Select RRS and site configuration
Task 3-4 – Develop simplified consequence model
Task 3-5 – Quantify consequence model

The relationship among these tasks is shown in Figures 17-1a, 17-1b, and 17-1c, and is further described below.

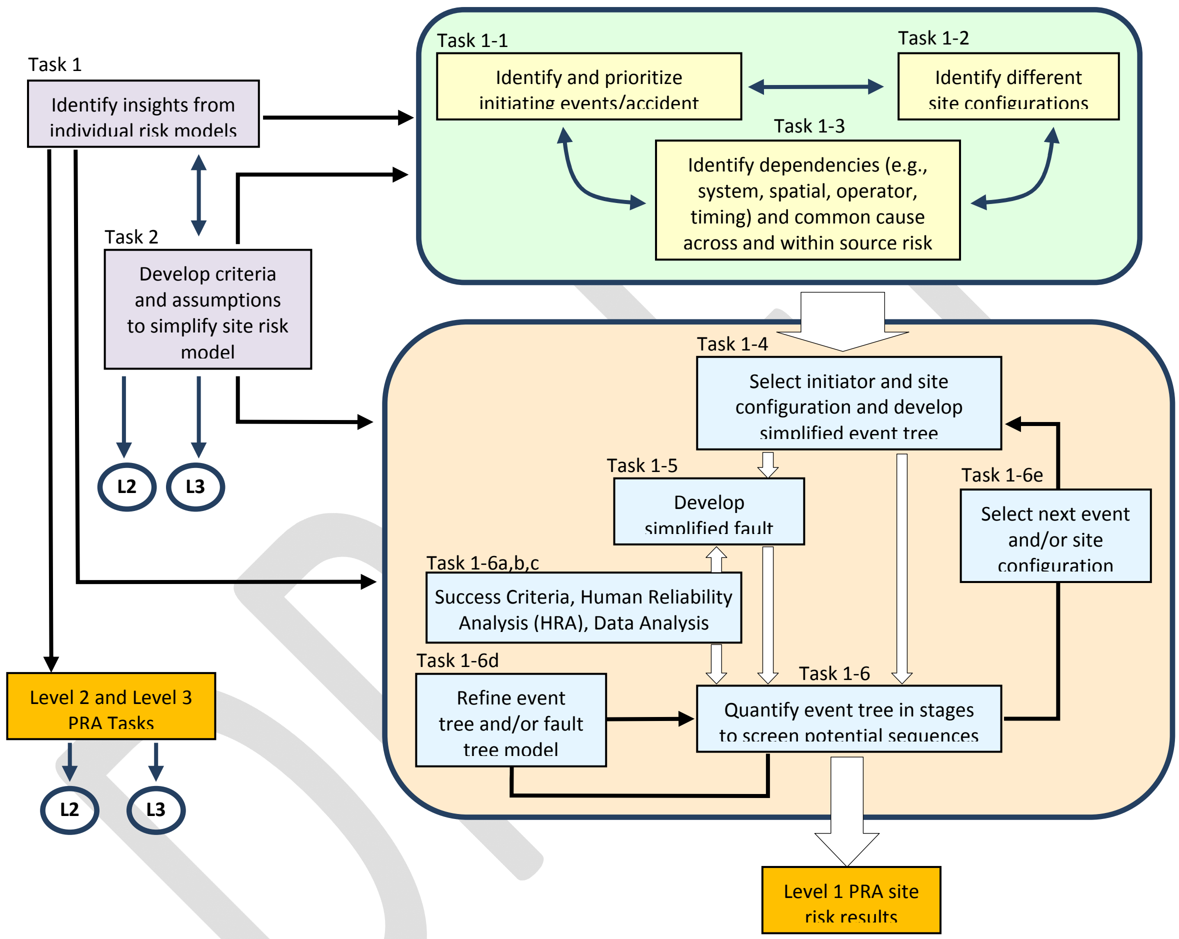

Figure 17-1a. Integrated Site Risk Analysis Flowchart (Level 1 PRA).

Task 1 – Identify Individual Risk Model Insights

The objective of this task, which supports the entire ISRA effort, is to identify insights from each individual single-source risk model to assist in developing criteria and assumptions that will be used in building each part of the integrated site risk model. These criteria and assumptions will be used to help prioritize, screen and simplify the analysis so that the ISRA task identifies and focuses on risk-significant multi-source sequences.

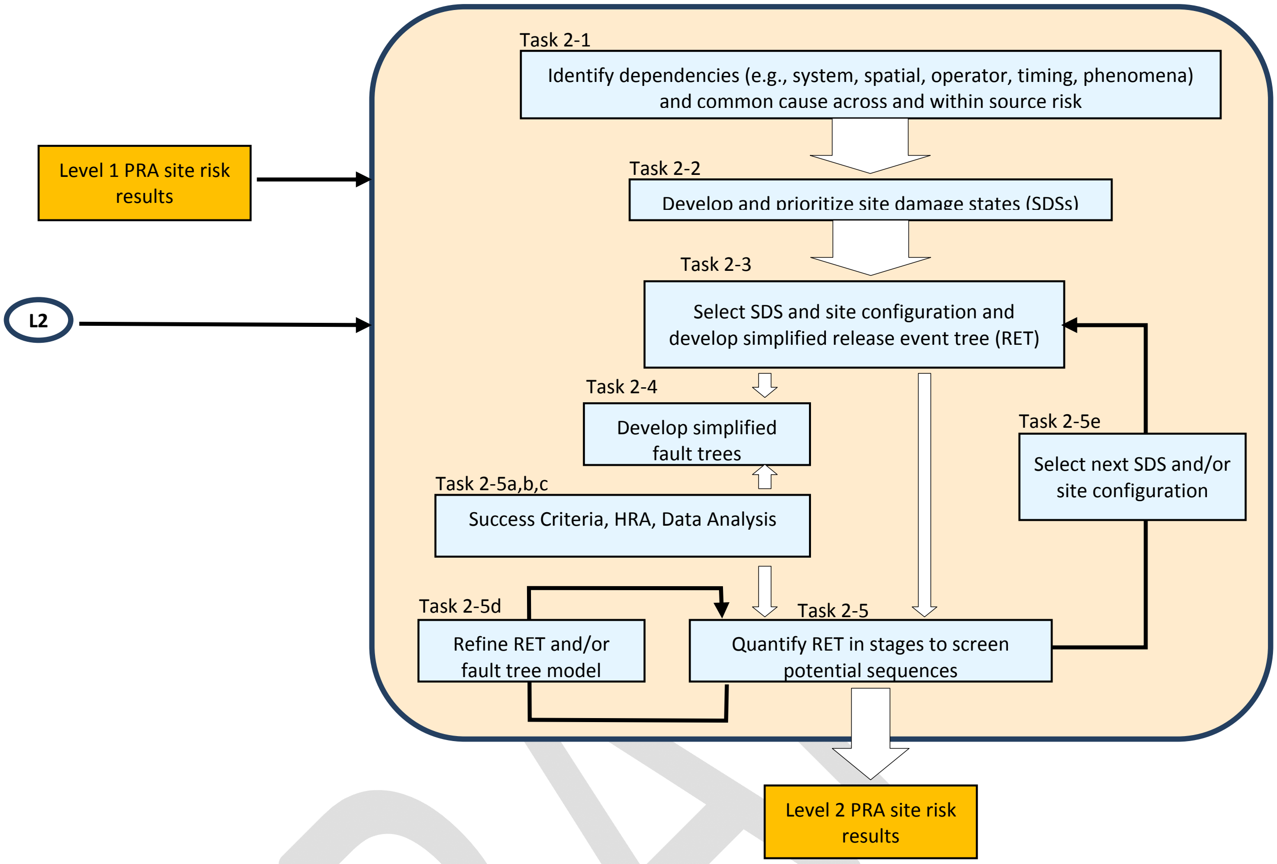

Figure 17-1b. Integrated Site Risk Analysis Flowchart (Level 2 PRA).

The single-source PRA models and plant information sources will be reviewed to identify features that have the potential to affect the delineation of multi-source accident sequences. Specifically, the review of the single-source PRA models and plant information sources will identify:

1. Shared support systems

2. Systems that have cross-connects between the units

3. Common locations (locations that house or provide access to equipment that support more than one source)

4. Credits (recovery actions) for the use of shared systems or cross-connects

During the review of the results of the single-source PRA models, the following information will be collected about risk-significant single-source accident sequences:

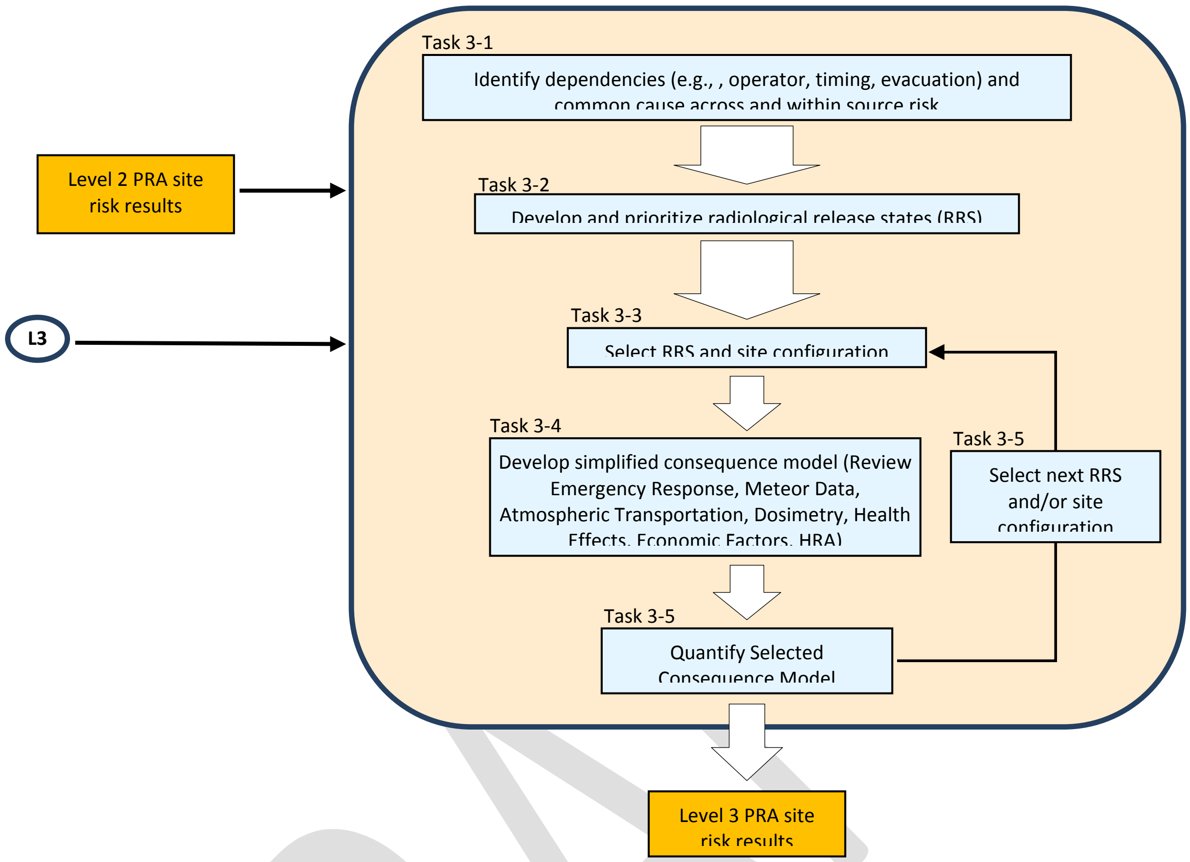

Figure 17-1c. Integrated Site Risk Analysis Flowchart (Level 3 PRA).

1. The initiating event
2. The plant operating state at the time of the initiator
3. The specific accident sequence (including events that were successful during the sequence)
4. The specific accident sequence timing (a chronology of the events that appear in a sequence) including (if appropriate), but not limited to:
   a. The time of battery depletion
   b. The time when water inventory sources deplete (e.g., when the switchover from ECCS injection to ECCS recirculation occurs)
   c. The time when operator actions need to be completed
5. Events that appear within the sequence cut sets which are potentially dependent with other sources (e.g., common-cause failures, shared systems, operator actions)

6. The sequence's contribution to the single-source risk estimate (frequency and consequence)

For the purposes of this review, a risk-significant sequence is one of the set of sequences, defined at the functional or systemic level that, when ranked, compose 95% of the risk, or that individually contribute more than ~1% to the risk. A variety of risk measures (e.g., individual early fatality risk, individual latent cancer fatality risk, population dose risk) will be used to help ensure that all risk-significant sequences are identified.

Task 2 – Develop Site Risk Model Selection Criteria and Assumptions

The objective of this task, which supports the entire ISRA effort, is to develop and apply screening and scoping approaches to the information collected in Task 1 in order to guide the development of the ISRA PRA logic models. Given the potentially large number of risk-significant single-source accident sequences that encompass all defined plant operating states, it is necessary to direct the ISRA's attention toward those sequences which have the potential to become risk-significant multi-source accident sequences. The following screening and scoping strategies will be considered during this task:

1. Screening on the likelihood of the specific site configuration

   Site configurations will be defined in Task 1-2. A site configuration specifies the initial and boundary conditions for each radiological source at the time when an initiating event occurs. For example, the Unit 1 reactor may be operating with its associated SFP in a nominal configuration, the Unit 2 reactor and its associated SFP may be in a refueling configuration, and the DCS facility may be in a nominal configuration when a seismic event occurs. Site configurations will be formed by superimposing the operating configurations defined within each single-source PRA model, with adjustments as necessary to account for logically impossible combinations or combinations prohibited by Technical Specifications.

   It may be acceptable to screening certain site configurations from further consideration if they have a low likelihood of occurrence. One specific objective of this task is to define what is meant by "a low likelihood of occurrence" of a site configuration. Screening on the likelihood of a site configuration may eliminate some configurations of particular interest (e.g., mid-loop operations) and, hence, will somewhat diminish the ability to provide multi-source risk insights. Therefore, the development and application of a screening strategy that considers the likelihood of a site configuration needs to balance the need to complete the ISRA task within the project's schedule and budget constraints against the desire to provide useful multi-source risk insights.

2. Screening on the partial multi-source sequence frequency

   A single-source sequence may cascade or propagate into other sources. With respect to the ISRA task:

   - A cascading sequence is an accident sequence which causes core damage or fuel damage in one source and, when combined with additional equipment failures or operator actions, also leads to core damage or fuel damage in another source. For example, a LOCA may occur in Unit 1 that is followed by a failure of ECCS, leading to core damage in Unit 1. In addition, the Unit 1 LOCA may also cause a LOOP in Unit 2 that progresses to SBO and core damage in Unit 2.

- A propagating sequence is an accident sequence which does not cause core damage or fuel damage in one source (i.e., it is a success path in the event tree) but, when combined with additional equipment failures or operator actions, leads to core damage or fuel damage in another source. For example, a LOCA may occur in Unit 1 that is successfully mitigated by operation of the ECCS. However, the Unit 1 LOCA may also cause a LOOP in Unit 2 that progresses to SBO and core damage in Unit 2.

It may be possible to screen some cascading or propagating sequences on low frequency by partially quantifying them and comparing the result to a specified truncation frequency. For example, consider a Unit 1 core-damage sequence that has a frequency of 1E-7/ry. If the probability of a consequential LOOP is 5E-3, then the partial multi-source sequence frequency would be 5E-10/ry (this result is a partial sequence frequency because it does not include the failures in Unit 2 that must occur to cause core damage). If a multi-source truncation frequency of 1E-9 is established, then this partial multi-source sequence would be screened from further consideration.

One specific objective of this task is to define acceptable multi-source truncation frequencies. It should be noted that truncation based on sequence frequency may occur at any stage of the ISRA (i.e., sequences may be screened using the fuel-damage frequency, the plant-damage-state frequency, or the release frequency).

3. Screening on the partial multi-source sequence risk

It may be possible to screen some cascading or propagating sequences on low risk by partially quantifying them and comparing the result to a specified truncation risk. For example, consider a Unit 1 core-damage sequence that has a frequency of 1E-6/ry. If the probability of a consequential LOOP is 5E-3, then the partial multi-source sequence frequency would be 5E-9/ry (= 1E-6/ry x 5E-3), which is above the 1E-9/ry truncation frequency used in the previous example. However, it is possible to approximate the consequences of the multi-source sequence by summing its individual contributors. For example, suppose that the conditional individual latent cancer fatality risk caused by the Unit 1 sequence is 1E-4 and that the conditional individual latent cancer fatality risk caused by the Unit 2 sequence is 5E-4. Then the approximate multi-source conditional individual latent cancer fatality risk would be 6E-4 (= 1E-4 + 5E-4), and the partial multi-source individual latent cancer fatality risk would be 3E-12/ry (= 5E-9/ry x 6E-4). If a multi-source truncation risk of 1E-10 is established, then this partial multi-source sequence would be screened from further consideration.

One specific objective of this task is to define an acceptable multi-source truncation risk for each consequence measure used in the project. The development and application of a screening strategy based on risk must consider the suite of risk metrics considered in the project.

The set of screening and scoping strategies will be reviewed by the project team, specifically including the Technical Advisory Group (TAG). This review, to be conducted before embarking on wide-scale implementation of the strategies, will include examples of the results produced by each strategy so that an assessment of the efficacy and efficiency of each strategy can be made.

Task 1-1 – Identify and Prioritize Initiating Events and Accident Sequence Combinations

The objective of this task is to identify and prioritize the possible combinations of single-source accident sequences that lead to core damage or fuel damage. Specifically, this task will apply the Task 2 screening criteria to the risk-significant single-source accident sequences identified in Task 1 in order to determine which single-source sequences should be combined, and the order in which they will be assessed.

In principle, multi-source accident sequences can be formed by combining individual sequences from each of the single-source PRA models. This task will be implemented in an iterative manner, starting with the risk-significant single-source accident sequences identified in Task 1. Based on a review of the intermediate results obtained, the multi-source PRA model will be expanded to incorporate additional sequences. This approach has several advantages:

- It maintains focus on determining risk-significant multi-source accident sequences
- It allows for the lessons learned from previous multi-source sequence delineation and solution to be fed back into subsequent analyses
- It allows the solution of multi-source accident sequences to be achieved within the limitations of existing PRA software

The set of initiating events in each single-source PRA will be divided into two broad classes:

1. Single-source initiators (SSIs): Initiators that occur in one source. SSIs generally include initiators caused by internal hazards such as internal events (e.g., loss of main feedwater, loss-of-offsite-power (LOOP) events[1], and loss-of-coolant accidents), internal floods, and internal fires. SSIs may cause multi-unit accidents due to cross-unit dependencies such as shared support systems, spatial interactions (e.g., flood propagation pathways), common-cause failures, or operator actions.

2. Common-cause initiators (CCIs): Initiators that simultaneously challenges all of the units at a multi-unit site. CCIs include initiators caused by external hazards (e.g., earthquakes, external floods, and severe weather).

The distinction between SSIs and CCIs is important when delineating multi-source accident sequences. As discussed in Task 2, a single-source sequence may cascade or propagate into other sources depending on the site configuration (to be defined in Task 1-2) and the nature of the dependencies among the sources (to be identified in Task 1-3). For example, consider the situation where both reactors are at-power, and the SFPs and DCS system are in a nominal configuration. A LOCA in the Unit 1 reactor (the SSI) may cause a consequential loss-of-offsite power (CLOOP) in Unit 1 and/or Unit 2. As a result, the CLOOP may initiate accident sequences in the Unit 2 reactor, the Unit 1 SFP, and/or the Unit 2 SFP.

In order to identify and prioritize cascading sequences, the single-source SSI-initiated accident sequences will be ranked-ordered (high-to-low) according to their sequence frequencies. Starting with the most likely sequence, each sequence will be reviewed to determine its

[1] Table 6-4 in NUREG/CR-6890 provides the conditional probability that all plants at a multi-unit site experience a LOOP given a LOOP at one of the plants at the site. The mean values for each LOOP category are 6% for plant-centered LOOPs, 21% for switchyard-centered LOOPs, 82% for grid-related LOOPs, and 69% for weather-related LOOPs. It is appropriate to classify LOOP events as SSIs since these conditional probabilities are not identically 100%.

potential to initiate an accident sequence in the remaining sources. The combination of events and circumstances that must occur to initiate a cascading sequence will be documented. This task will be iterative with Task 1-2 (the identification of site configurations), Task 1-3 (the identification of dependencies), the development of accident sequence logic models (event trees in Task 1-4 and fault trees in Task 1-5), and Task 1-6 (logic model quantification).

In order to identify and prioritize propagating sequences, the single-source SSIs will be rank ordered (high-to-low) according to their occurrence frequencies. Starting with the most likely SSI, each SSI will be reviewed to determine its potential to initiate an accident sequence in the remaining sources. The combination of events and circumstances that must occur to initiate a propagating sequence will be documented. This task will be iterative with Task 1-2 (the identification of site configurations), Task 1-3 (the identification of dependencies), the development of accident sequence logic models (event trees in Task 1-4 and fault trees in Task 1-5), and Task 1-6 (logic model quantification).

The list of CCIs will be prioritized according to their occurrence frequencies. Note that, by definition, there is no need to consider how they can initiate accident sequences in multiple sources.

Task 1-2 – Identify Different Site Configurations

The objectives of this task are to define site configurations and to estimate their likelihoods.

As previously discussed under Task 2, a site configuration specifies the initial and boundary conditions for each radiological source at the time when an initiating event occurs. Site configurations will be formed by superimposing the operating configurations defined within each single-source PRA model, with adjustments as necessary to account for logically impossible combinations or combinations prohibited by Technical Specifications.

For example, the reactor PRAs (including the at-power PRA and the shutdown and low-power PRA) will define a set of plant operating states (e.g., at-power, cooldown, refueling, and startup). In a similar manner, the SFP will define a set of operating cycle phases (e.g., nominal, outage entry, refueling, post-refueling, and cask loading). The DCS PRA will have an analogous set of operating cycle phases (e.g., nominal and cask loading). A complete set of site configurations could be developed by selecting a specific plant operating state for each reactor, a specific operating cycle phase for each SFP, and a specific operating cycle phase for the DCS. Some of these combinations will be logically impossible and, therefore, can be eliminated. For example, it is not possible for a reactor to be at-power while its associated SFP is in a refueling configuration.

In addition, it may be possible to use symmetry to further reduce the set of site configurations that need to be considered in the ISRA task. For example, a site configuration where Unit 1 is operating and Unit 2 is in refueling is logically equivalent to a site configuration where Unit 1 is in a refueling configuration and Unit 2 is operating.

Task 1-3 – Identify Dependencies and Common Causes

The objective of this task is to identify dependencies among the radiological sources that are potentially important to the assessment of multi-source risk. Examples of dependencies include:

- Shared systems or systems that have cross-connects between the units

- For example, the Unit 1 AC power system supports the Unit 1 reactor and the Unit 1 SFP
- For example, Units 1 and 2 are electrically interconnected through the site switchyard

- Common locations (locations that contain equipment which supports two or more radiological sources)
  - For example, Units 1 and 2 share a common control room
- Multiple operator actions (including the potential for resource constraints, lack of training or guidance on addressing multi-source sequences, and command-and-control issues)
- Situations where accessibility or habitability may be impaired due to the accident sequence (e.g., high temperature work environment, high radiation levels)
- Common-cause failures

This task reviews plant information and the single-source PRA models in order to identify and understand the dependencies that have been modeled. This effort is a necessary prelude to the delineation of multi-source accidents sequences. Failure to account for multi-source dependencies will result in underestimating the frequency of the multi-source accident sequences. At the same time, PRA results are typically driven by dependencies; therefore, knowledge of the potential multi-source dependencies can be used to simplify the multi-source logic models so that they may be solved within a reasonable time.

The results of the review performed during this task will be documented in a set of dependency matrices. Regardless of the exact format of these dependency matrices, they must:

- Accurately reflect the identified dependencies
- Provide the ability to identify and understand dependencies that span multiple radiological sources (e.g., shared support systems between a reactor and its associated spent fuel pool)
- Provide traceability to reference documentation

Task 1-4 – Develop Simplified Event Trees

The objective of this task is to develop a set of simplified event trees that delineate multi-unit accident sequences. The reasons for using simplified event trees include (a) achieving a model solution in a reasonable time period, and (b) focusing attention on identifying and analyzing risk-significant multi-source risk contributors.

As shown in Figure 17.2, the simplified event trees initiated by CCIs will be developed by beginning with the single-source events trees for the Unit 1 reactor. The sequences in these event trees that result in core damage will be linked to the single-source event trees for the Unit 1 SFP. Continuing the process, the fuel-damage endstates will be linked to the Unit 2 reactor event trees, to the Unit 2 SFP, and finally to the DCS event trees. This order is preferred since there are dependencies between the Unit 1 reactor and SFP trees (electric power, service water, operator actions) and between the Unit 2 reactor and SFP trees. Since the event trees will be progressively quantified, applying the screening and scoping strategies developed in

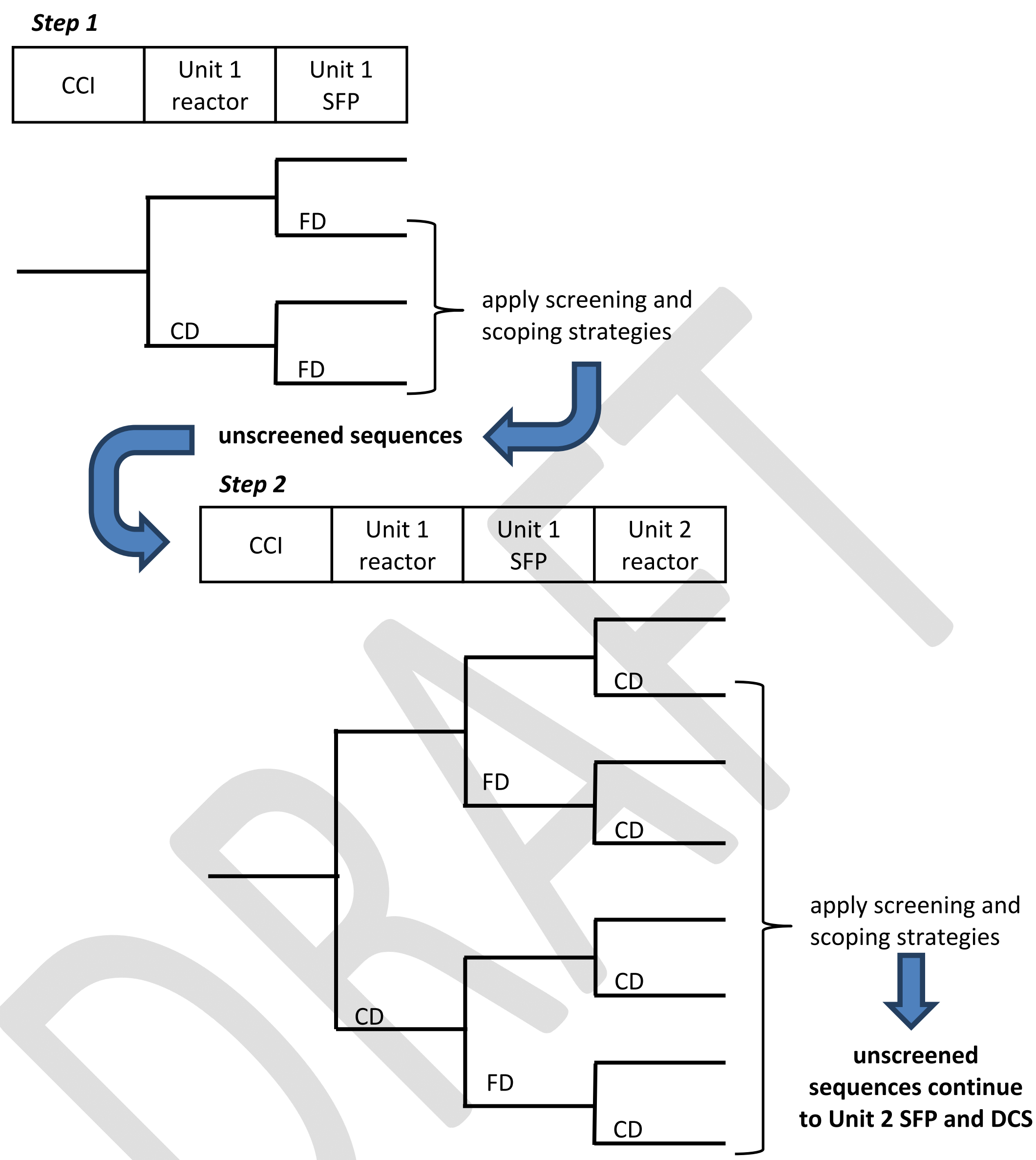

Figure 17-2. Development of Event Tree Logic for Common-Cause Initiators.

Task 2, this approach helps to ensure that dependencies are properly captured and assessed before sequences are screened.

Simplified event trees for SSIs will be developed in a similar manner, as shown in Figure 17-3. Note that it is necessary to include initiating event logic for the "downstream" radiological sources in order to determine which accident sequences propagate or cascade.

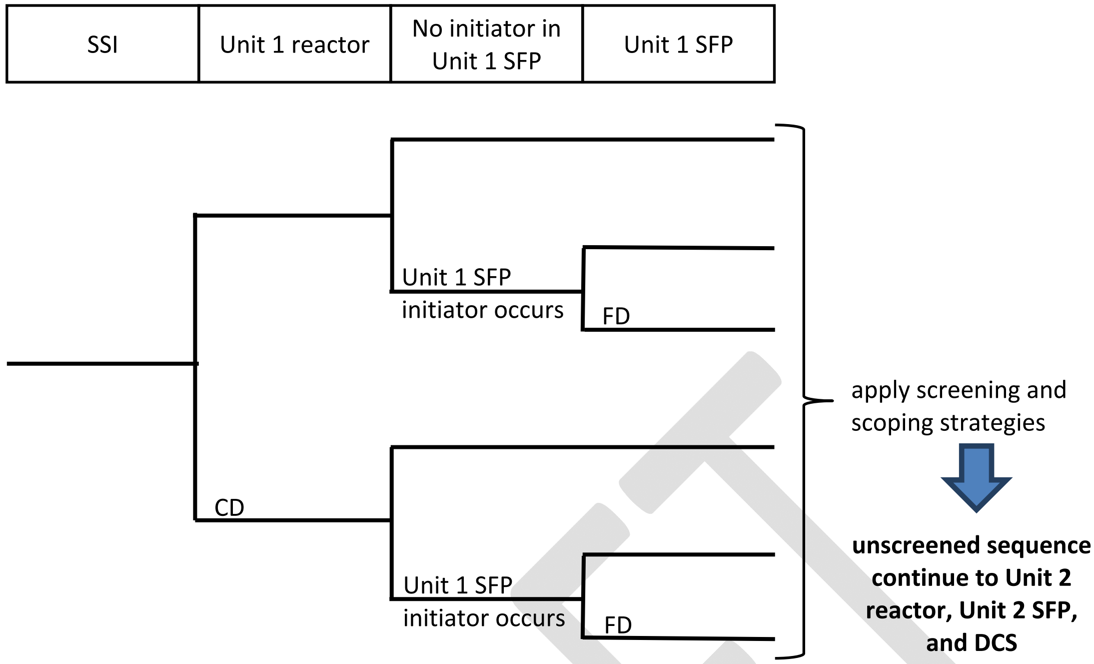

Figure 17-3. Development of Event Tree Logic for Single-Source Initiators.

A variety of techniques will be used to simplify the multi-source events trees, such as:

1. Removal of duplicate event tree headings.

2. Restructuring the logic to expedite the solution process.

3. Linking only those partial multi-source sequences that have not been screened out.

It is anticipated that the development of simplified event trees will be an iterative process, based on the insights obtained from initial logic model solution as further discussed in Task 1-6d below.

Task 1-5 – Develop Simplified Fault Trees

The objective of this task is to develop simplified fault trees based on the detailed fault trees developed during the single-source PRAs. The reasons for using simplified fault trees include (a) achieving a model solution in a reasonable time period, and (b) focusing attention on identifying and analyzing risk-significant multi-source risk contributors.

A variety of techniques will be using to simplify the detailed single-source fault tree models, such as:

1. Identifying independent subtrees which can be collapsed into “supercomponents” that consist of basic events which are independent of other basic events in the models,as shown in Figure 17-4.

2. Restructuring fault trees to expedite their solution (e.g., moving events that appear on both sides of an AND gate upwards in the logic).

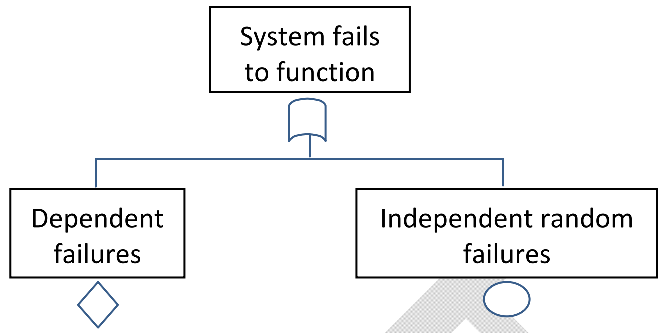

Figure 17-4. Fault Tree Logic Simplification.

Dependencies among the various sources (e.g., shared support systems, cross-unit common-cause failures) will be incorporated into the fault trees as appropriate, according to the information developed in Task 1-3.

It is anticipated that the development of simplified fault trees will be an iterative process, based on the insights obtained from initial logic model solution as further discussed in Task 1-6d below.

Task 1-6 – Quantify Accident Sequence Event Trees

The objective of this task is to quantify the multi-source accident sequence models developed in Tasks 1-4 (multi-source accident sequence event trees) and 1-5 (supporting fault trees).

Multi-source accident sequence events trees will be quantified on an individual basis, according to the prioritized lists of SSIs and CCIs developed in Task 1-1. The phrase “individual basis” means that each event tree will be quantified separately as opposed to simultaneously solving all event trees in a single quantification run (as is typically done during a single-source PRA). The reason for using an individual basis is to obtain solutions in a reasonable timeframe, thereby enabling their timely review and incorporating model corrections back into the quantification process. (It is anticipated that the ISRA task will produce a large set of multi-source logic models which will require substantial computer solution time. Quantifying the entire set of models at one time is not an efficient use of the available project analysts.)

During the solution of each multi-source event tree, the screening and scoping strategies developed in Task 2 will be used to focus on identifying and analyzing risk-significant multi-source risk contributors.

There are five supporting and interrelated subtasks for multi-source logic model solution, as described below.

Task 1-6a – Success Criteria

Since the multi-source accident sequence models will be based on the single-source PRA models, they will reflect the success criteria used to develop those models. However, review of the solution of the multi-source accident sequence models may call into question some of these underlying success criteria. In addition, there may be a need to conduct additional success criteria calculations in order to obtain information about the timing or sequencing of events in the multi-source accident sequence models.

Task 1-6b – Supporting Human Reliability Analysis

It is expected that dependent operator actions within each single-source PRA model will have been addressed during their separate analysis (Sections 12-16). The purpose of this subtask is to confirm that these dependencies have been retained in the simplified event trees and fault trees, and to analyze the possible combinations of operator actions that appear in the solution of the multi-source sequence models for possible dependencies. Of specific concern to the ISRA task is the identification of:

1. The need for multiple concurrent operator actions at multiple sources, which may overburden the available personnel resources at the site

2. Situations where site accessibility or habitability may be impaired due to the accident sequence (e.g., high temperature work environment, high radiation levels)

It is anticipated that some of the human failure events (HFEs) defined in the single-source PRA models may not be appropriately defined when the multi-source accident sequence context is considered. A review of the multi-source accident sequence minimal cut sets, considering the information gathered in Task 1, will be used to determine if the existing HFEs need to be modified or if new HFEs need to be created.

Task 1-6c – Supporting Data Analysis

Additional data needed to support the quantification of multi-source accident sequences will be developed during this subtask (e.g., the probability of CLOOP).

Task 1-6d – Refine Event Tree and Fault Tree Models

It is anticipated that the multi-source accident sequence event trees and supporting fault trees will require revision, based on the results of the initial quantification efforts. In addition to correcting errors, logic model revisions may be needed to properly account for dependent operator actions, to accommodate sequence solution within the limitations of the SAPHIRE software, or to expand the simplified logic in order to achieve an appropriate level of detail in the analysis. The results of the simplified models developed in Tasks 1-4 and 1-5 will be compared to the more detailed single-source PRA results to ensure that the ISRA models have not been overly simplified to the point where important dependencies or risk contributors have been omitted.

Task 1-6e – Select Next Event and/or Site Configuration

Using the prioritized lists of SSIs and CCIs developed in Task 1-1, along with the lessons learned during the quantification of previous event trees, the subtask will determine the order of event tree quantification.

Task 2-1 – Identify Dependencies and Common Causes

The objective of this task is to identify dependencies among the radiological sources that are potentially important to the assessment of multi-source risk. Task 1-3 will generally identify dependencies that are important to the ISRA task as a whole and specifically to the development of the multi-source Level 1 PRA logic models. In contrast, this task will focus on identifying dependencies that are specific to development of the multi-source Level 2 PRA logic models.

Analogous to Task 1-3, this task reviews plant information and the single-source PRA models in order to identify and understand the dependencies that have been modeled. This effort is a necessary prelude to the delineation of multi-source accidents sequences. Failure to account for multi-source dependencies will result in underestimating the frequency of the multi-source accident sequences. At the same time, PRA results are typically driven by dependencies; therefore, knowledge of the potential multi-source dependencies can be used to simplify the multi-source logic models so that they may be solved within a reasonable time. As in Task 1-3, the results of the review performed during this task will be documented in a set of dependency matrices.

Task 2-2 – Identify and Prioritize Site Damage States

The objective of this task is to identify and prioritize site damage states (SDSs).

The reason for defining SDSs is to coalesce the results of the ISRA Level 1 PRA into a manageable set of accident scenarios that summarize the various core damage and fuel damage sequences. The SDSs will form the basis for developing the multi-source release event trees (RETs), which will developed in Task 2-3. In contrast to the single-source Level 2 PRAs, the ISRA will not link each multi-source Level 1 sequence to the multi-source RETs because such an approach ignores the insights gained from applying the Level 1 screening and scoping approach, and also is likely to generate very large logic structures which cannot be readily solved using current PRA software.

SDSs will be developed by combining the lists of attributes defined for each of the single-source damage states[2]. Bridging logic (either a bridge event tree or a set of Boolean rules) derived from the single-source RETs may be developed to assist in defining multi-source SDSs. The occurrence frequency of each SDS will be determining by summing the individual multi-source sequence frequencies that contribute to the SDS.

The screening and scoping strategies developed in Task 2 will be applied to prioritize the SDSs. Specifically, the SDSs will be rank ordered (high-to-low) according to their occurrence frequencies. A second rank ordering based on estimated risk (developed from consideration of the insights gained through review of the single-source PRA results, as developed in Task 1) will be developed. The final prioritization of multi-state SDSs will be made on a subjective basis, considering the two rank-ordered lists and incorporating the lessons learned as the multi-source Level 2 PRA is developed and quantified.

Task 2-3 – Develop Simplified Release Event Trees

The objective of this task is to develop a set of RETs that delineate multi-unit release sequences. The reasons for using simplified event trees include (a) achieving a model solution

[2] For reactors, the single-source damage state is typically called a "plant damage state (PDS)." The more generic phrase "single-source damage state" includes both PDSs related to the reactors and their equivalents for spent fuel.

in a reasonable time period, and (b) focusing attention on identifying and analyzing risk-significant multi-source risk contributors.

For each of the SDSs defined in Task 2-2, a simplified RET will be developed by beginning with the RET for the Unit 1 reactor[3]. The sequences in this RET that result in offsite release will be linked to the single-source RET for the Unit 1 SFP. Continuing the process, the fuel-damage releases will be linked to the Unit 2 reactor event trees, to the Unit 2 SFP, and finally to the DCS event trees. This order is preferred since there are dependencies between the Unit 1 reactor and SFP trees (electric power, service water, operator actions) and between the Unit 2 reactor and SFP trees. Since the RETs will be progressively quantified, applying the screening and scoping strategies developed in Task 2, this approach helps to ensure that dependencies are properly captured and assessed before sequences are screened.

It may also be possible to develop a single multi-source RET that applies to a group of SDSs. This approach has the advantage that it promotes self-consistence within the analysis, which needs to be balanced against the additional complexity that it entails.

A variety of techniques will be used to simplify the multi-source RETs, as discussed under Task 1-4. It is anticipated that the development of simplified RETs will be an iterative process, based on the insights obtained from initial logic model solution as previously discussed in Task 1-6d.

Task 2-4 – Develop Simplified Fault Trees

The objective of this task is to develop simplified fault trees based on the detailed fault trees developed during the single-source PRAs. The reasons for using simplified fault trees include (a) achieving a model solution in a reasonable time period, and (b) focusing attention on identifying and analyzing risk-significant multi-source risk contributors.

A variety of techniques will be using to simplify the detailed single-source fault tree models, as discussed under Task 1-5. Dependencies among the various sources (e.g., shared support systems, cross-unit common-cause failures) will be incorporated into the fault trees as appropriate, according to the information developed in Task 2-1. It is anticipated that the development of simplified fault trees will be an iterative process, based on the insights obtained from initial logic model solution as previously discussed in Task 1-6d.

Task 2-5 – Quantify Release Event Trees

The objective of this task is to quantify the multi-source accident sequence models developed in Tasks 2-3 (multi-source release event trees) and 2-4 (supporting fault trees).

Multi-source release event trees will be quantified on an individual basis, according to the prioritized list of SDSs developed in Task 2-2. The phrase “individual basis” means that each event tree will be quantified separately as opposed to simultaneously solving all event trees in a single quantification run (as is typically done during a single-source PRA). The reason for using an individual basis is to obtain solutions in a reasonable timeframe, thereby enabling their timely review and incorporating model corrections back into the quantification process. (It is anticipated that the ISRA task will produce a large set of multi-source logic models which will require substantial computer solution time. Quantifying the entire set of models at one time is not an efficient use of the available project analysts.)

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[3] For reactors, the release event tree is typically called a “containment event tree (CET).” The more generic phrase “release event tree” includes the reactor CETs and their equivalents for spent fuel.

During the solution of each multi-source event tree, the screening and scoping strategies developed in Task 2 will be used to focus on identifying and analyzing risk-significant multi-source risk contributors.

There are five supporting and interrelated subtasks for multi-source logic model solution, as listed below.

Task 2-5a – Success criteria

Task 2-5b – Supporting human reliability analysis

Task 2-5c – Supporting data analysis

Task 2-5d – Refine event tree and fault tree models

Task 2-5e – Select next event and/or site configuration

These tasks are analogous to Tasks 1-6a thru 1-6e (described previously).

Task 3-1 – Identify Dependencies and Common Causes

The objective of this task is to identify dependencies and common causes that affect the development of the multi-source consequence models.

In general, multi-source radiological release states (RRSs) can be developed by superimposing the single-source RRSs that participate in a given release sequence, recognizing that a multi-source release sequence needs to be characterized by multiple plume segments. However, it must be recognized that superimposing the single-source RRSs may ignore important dependencies pertaining to release sequence timing (e.g., when does evacuation of the surrounding site actually begin?). A chronology for each multi-source RRS will be developed to help ensure that timing dependencies are taken into account and to provide input to the MACCS2 analysis (Task 3-4).

Task 3-2 – Identify And Prioritize Radiological Release States

The objective of this task is to identify and prioritize RRSs by utilizing the RRSs defined in the single-source PRA and making adjustments as needed to ensure that each multi-source RRS is self-consistent.

As discussed under Task 3-1, multi-source RRSs can be developed by superimposing the single-source RRSs that participate in a given release sequence, recognizing that a multi-source release sequence needs to be characterized by multiple plume segments. In MACCS2, the plume segments that comprise a release can be separated by a time gap, can directly follow the preceding segment, or they can overlap. Different release heights, heat contents, release durations, and initial values for the plume dimension (σ_y and σ_z) may be assigned to each plume. Only one particle size distribution may be assigned to each chemical element group.

When defining multi-source RRSs, it will be necessary to adjust some of the protective action parameters (in particular, those parameters that define the emergency evacuation) used in the single-source RRSs that comprise the multi-source RRS. It is assumed that evacuation will be triggered by the earliest release, regardless of which source is causing the release.

Given the potentially large number of single-source accident sequences that encompass all defined plant operating states, it is necessary to direct the ISRA's attention toward those sequences which have the potential to become risk-significant multi-source accident sequences. The following screening and prioritization strategies will be considered during this task:

1. Rank-ordering (high-to-low) the possible multi-source release sequences according to their frequencies, and then focusing on the most likely sequences.

2. Rank-ordering (high-to-low) the consequences of the single-source release sequences in order to predict which multi-source RRSs will have the highest consequences. A separate ranking needs to be made for each consequence measure addressed in the project.

3. Considering the combination of RRS frequency and predicted consequences in order to focus attention on those RRSs that are anticipated to be significant risk contributors.

Task 3-3 – Select RRS and Site Configuration

The objective of this task is to implement the screening and prioritization strategies developed in Task 3-2 in order to select specific multi-source RRSs for subsequent analysis. It is anticipated that the initial prioritization scheme may be adjusted as the project proceeds in order to incorporate the lessons learned from previous multi-source consequence calculations.

Task 3-4 – Develop Simplified Consequence Model

The objective of this task is to develop the MACCS2 input deck needed to estimate the consequences of the multi-source RRSs selected in Task 3-3. The guidance in TAAP Section 12.3 will be used for the following areas:

1. Protective action parameters and other site data (Subtask 1-3.2)

2. Meteorological data (Subtask 1-3.3)

3. Atmospheric transport and dispersion (Subtask 1.3-4)

4. Dosimetry (Subtask 1.3-5)

5. Health effects (Subtask 1-3.6)

6. Economic factors (Subtask 1.3-7)

Task 3-5 – Quantify Consequence Model

The objective of this task is to quantify the consequence models developed in the previous steps, generating the results in the form of the consequence metrics of interest and identifying significant contributors to the calculated consequence measures/metrics. Guidance in TAAP Section 12.3, Subtask 1-3.8 (Quantification and Reporting) will be used.

The consequences of multi-source release sequences, as calculated using MACCS2, will be compared to the screening estimates of consequences (made by summing the consequences of the individual sources that contribute to the multi-source sequences) to confirm the adequacy of the risk screening approach used in Task 2.

17.5 Documentation

The products of the ISRA task are identified below. These products (along with the identified inputs, Section 17.2) and the documentation requirements provided in Section 18 should be sufficient for an independent analyst to understand how the analysis was performed and to reproduce the results. Table 17-1 provides the expected products.

Table 17-1. Integrated Site Risk Assessment Products.

ISRA Task	Description
Task 1	Single-Source Level 1 PRA Insights
Tasks 1 and 3-1	Single-Source Level 2/3 PRA Insights
Task 2	Scoping and Screening Strategies
Task 1-1	Prioritized List of Level 1 PRA Multi-Source Sequences
Task 1-2	Site Configurations
Tasks 1-3 and 2-1	System Dependencies Matrices
Tasks 1-3 and 2-1	List of Common Locations
Tasks 1-3 and 2-1	List of Multiple Operator Actions
Tasks 1-3 and 2-1	List of Common-Cause Failures
Task 1-4	Simplified Level 1 ISRA Event Trees
Tasks 1-5 and 2-4	Simplified ISRA Fault Trees
Task 1-6	Level 1 ISRA Results
Tasks 1-6a and 2-5a	ISRA Supporting Success Criteria Analysis
Tasks 1-6b and 2-5b	ISRA Supporting Human Reliability Analysis
Tasks 1-6c and 2-5c	ISRA Supporting Data Analysis
Task 2-2	Prioritized List of Multi-Source Plant Damage States
Task 2-3	Simplified ISRA Release Event Trees
Task 2-5	Level 2 ISRA Results
Task 3-2	Prioritized List of Multi-Source Radiological Release States
Task 3-4	ISRA Consequence Models
Task 3-5	Level 3 ISRA Results

17.6 Task Interfaces

The ISRA task interfaces with every project task, as shown in Figure 17-5. Thick black lines show the flow of information among the ISRA task (iteration loops are not shown to promote clarity). Development of information and models in the single-source PRAs are shown with thin black lines. Primary interfaces between the ISRA task and the single-source PRA tasks are shown with thick colored lines. Specifically, thick light blue lines show the flow of risk insights that will be used in Task 1 to assist in developing criteria and assumptions that will be used in building each part of the integrated site risk model. Thick red, green, and dark blue lines show the flow of single-source logic models (reactor at-power internal hazards PRA – Section 12, reactor at-power external hazard PRA – Section 13, reactor shutdown and low-power all hazards PRA – Section 14, spent fuel pool PRA – Section 15, and the dry cask storage PRA – Section 16) into the ISRA (Tasks 1-1 to 1-6, Tasks 2-1 to 2-5, and Tasks 3-1 to 3-5). Dashed black lines show the interface with tasks that support the project as a whole (success criteria – Section 4, systems analysis – Section 5, data analysis – Section 6, human reliability analysis – Section 7, structural analysis – Section 8, fragility analysis – Section 9, hazard analysis – Section 10, and uncertainty analysis – Section 11). Finally, quality assurance (Section 18) is shown as an overarching task that applies to the entire project.

It is essential that development of the single-source PRAs be coordinated with the ISRA development effort to ensure that the individual pieces can be coherently integrated. Figure 17-5 illustrates this need (indicated by the use of double arrowheads). The review of the single-source PRA models and plant information sources and the compilation of risk insights (Task 1) will provide a detailed understanding of the single-source PRA models. The single-source PRA models will not be directly integrated (linked together) to form the multi-source PRA models; rather, they provide the “raw material” used to develop the simplified ISRA PRA models (developed in Tasks 1-4, 1-5, 2-3, and 2-4). However, it is important to maintain functional and logical consistency between the more detailed single-source PRA models and the simplified ISRA PRA models. The following approaches will be used to achieve this end:

1. Frequent and substantive Task Leader meetings.
2. One-on-one meetings with other Task Leaders.
3. Documentation of modeling issues as specified in Section 18 (Quality Assurance), and prompt resolution of these issues.
4. Comparison of results to the single-source PRA results as the IRSA is progressively developed.

17.7 References

1. D. Chanin, et al., “Code Manual for MACCS2: User’s Guide,” NUREG/CR-6613, Vols. 1 and 2, May 1998.

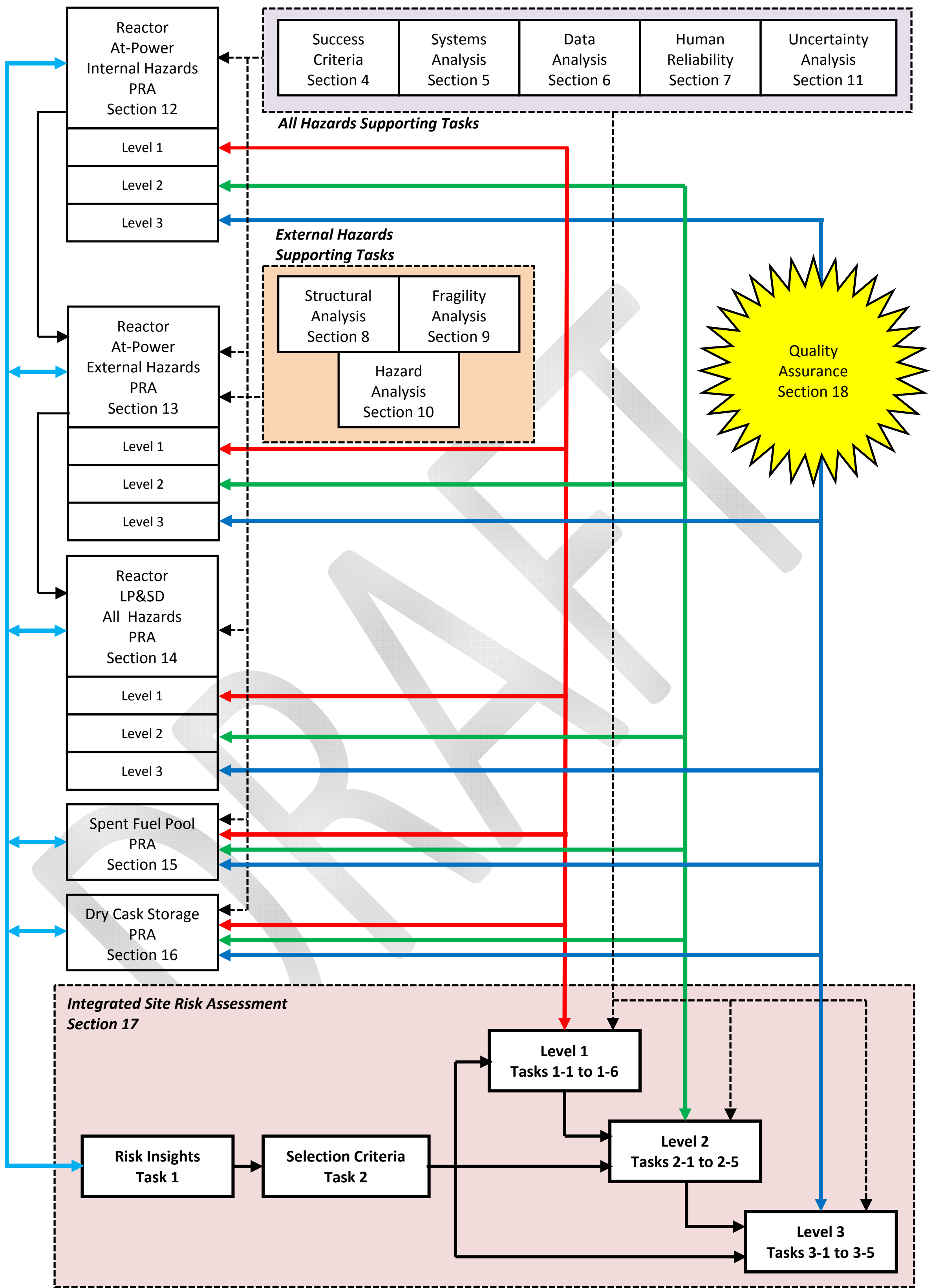

Figure 17-5. Task Interfaces and Information Flow.