

FAQ Number 13-0002 FAQ Revision 0n1

FAQ Title Modeling of Main Control Room Abandonment on Loss of Habitability

Plant: Various Date: 16~~3~~ AugustJuly 2013

Contact: P. Amico, Hughes Assoc. Phone: 443.745.2360

J. Julius, SCIENTECH 800-862-6702

Email: pamico@haifire.com

jjulius@curtisswright.com

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**Purpose of FAQ:**

To clarify the expectation for modeling of control room abandonment for fire scenarios in the main control room (MCR) that lead to a loss of habitability.

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**Relevant NRC document(s):**

NUREG-1921, NUREG/CR-6850

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**Details:**

**NRC document needing interpretation (include document number and title, section, paragraph, and line numbers as applicable):**

NUREG-1921 and NUREG/CR-6850, specifically they regard the assessment in fire PRA of MCR abandonment in a manner adequate to support risk-informed applications. This is accomplished by performing detailed analyses for the estimation of human error probabilities (HEPs) for risk-significant human failure events (HFEs), and the use of screening/scoping values for HEPs for non-significant MCR scenarios. The guidance is specifically found as follows:

NUREG-1921, specifically Sections 4.8, 5.1.3, 5.2 and 5.3 as it regards assessment of MCR abandonment, and Section 4.3 as it regards feasibility assessment.

NUREG/CR-6850, Volume 1 Section 3.2.7 and Volume 2 Sections, 11.5.2, 11.5.3, 12.5.3 and 12.5.5.2 as they regard assessment of MCR abandonment.

**Circumstances requiring interpretation or new guidance:**

Fire PRAs performed by the industry have modeled MCR abandonment scenarios in different ways. NRC has expressed concern about the diversity of approaches being used, and feels that further guidance on implementation, beyond what is currently provided in NUREG-1921 and NUREG/CR-6850 is needed. In the interests of

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reaching agreement between the industry and NRC as to how the modeling can be done this FAQ is being issued.

Main control room abandonment is a complex issue in that the PRA modeling consists of a wide range of scenarios and the plant response consists of a collective set of operator actions. In addition to issues related to multiple scenarios and multiple operator actions, there are issues related to limitations in the current human reliability analysis (HRA) methods that make the modeling difficult. It was recognized in NUREG-1921 that the issue of main control abandonment was one requiring future HRA research.

As a result of these issues, Fire PRAs performed by the industry to date have modeled main control room (MCR) abandonment scenarios using different quantification approaches and different levels of detail. For example, in some Fire PRA models a single, overall human error probability (HEP) of 0.1 representing the collective set of operator actions needed to safely shutdown the plant following a fire in the Main Control Room (MCR) or a fire in the cable spreading rooms has been modeled. This single HEP may have been applied to all main control room fire scenarios that led to evacuation due to loss of habitability (LOH). Several reviews have questioned the validity of applying a single representative HEP (or CCDP) to the range of scenarios that would be encountered, each of which potentially involves many operator actions, even though this may be "allowed" by NUREG-1921. This FAQ provides guidance to the MCR Abandonment modeling on loss of habitability, including when a single-screening/scoping HEP is appropriate and when a plant-specific, detailed human error probability (or set of human error probabilities) should be developed for each fire scenario. Further, this FAQ defines specific issues to be addressed.

No new methods are required or suggested with regard to these circumstances; therefore the use of a FAQ to reach agreement on guidance for MCR abandonment modeling is appropriate. Main control room fire scenarios that do not lead to abandonment, whether or not they require actions to be taken outside the MCR, are not in the scope of this FAQ. as they are related to LOC.

The term "MCR abandonment fire scenario on loss of habitability (LOH)" in this FAQ is defined as a fire scenario occurring on the MCR that creates environmental conditions leading to a demand to shift command and control of the plant from the MCR to a remote shutdown panel or a set of local control stations. MCR LOH abandonment scenarios consist of the following elements, with some elements addressed in this FAQ (as noted below) and some elements addressed using existing guidance (requiring no amplification in this FAQ).

- 1) Fire ignition, growth and suppression (Not addressed in this FAQ)
- 2) Demand for abandonment due to loss of habitability (LOH). (Addressed in this FAQ)

**Comment [p1]:** This is not really true. For example, an MCR fire on a particular panel may not lead to either LOH or LOC, just a loss of some equipment that would need to be dealt with. We suggest the alternative wording shown.

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- 2)3) Assessment of the feasibility of the actions required for abandonment. (Not at issue; therefore out of scope of this FAQ. No credit for abandonment can be applied unless the actions are shown to be feasible. This is well understood and agreed to, and the guidance in NUREG-1921 is adequate as it stands. As there is no need for further interpretation or new guidance, it is not addressed in this FAQ.
- 3)4) Operator decision to abandon or not abandon. (For LOH scenarios, not an issue; therefore out of scope of this FAQ)
- 4)5) Operator actions inside of the MCR to:  
a. Transfer control outside of the MCR, which would include  
i. ~~isolate~~ MCR circuits and  
a-ii. activate a remote shutdown panel/local control stations; and  
b. Mitigate spurious actuation (e.g. to shut the pressurizer PORV block valve in a PWR). (Addressed in this FAQ)
- 5)6) Operator actions outside of the MCR to safely shutdown the plant, including  
a. Actions performed at a remote shutdown panel or local control stations to establish front-line systems to mitigate a transient loss of decay heat removal. (Addressed in this FAQ)  
b. Actions performed to align and energize support systems as needed by front-line systems. (Addressed in this FAQ)
- 6)7) Operator actions outside of the MCR to isolate MCR circuits and to mitigate spurious actuation (e.g. to shut the pressurizer PORV block valve in a PWR). (Addressed in this FAQ)
- 7)8) SSC equipment reliability and operability for components used in the plant response. (Addressed in this FAQ)

**Comment [O2]:** If this action is supposed to represent those actions needed for "switchover" of control outside MCR, we ought to state this explicitly. All switchover actions should be represented. If this action isn't intended to represent that, the "switchover" action(s) needs to be identified explicitly.

**Comment [p3]:** Agreed. Wording has been changed to improve clarity.

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## Specific circumstances requiring interpretation or new guidance:

- When a screening/scoping approach is appropriate for MCR Abandonment, and when a detailed analysis is needed.
- Identification of the set of operator actions which are required for safe shutdown, and the set of operator actions that directly mitigate spurious cable faults.
- Definition of the execution tasks and associated success criteria for each operator action given the context of the fire scenarios.
- Qualitative analysis associated with individual operator actions and the overall collective set of actions, including the analysis of time-critical actions.
- Feasibility considerations
- Quantification method selection
- Conduct of a reasonableness check

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**Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:**

There have been plants that have used a generic value of 0.1 for the probability of failure to reach a safe and stable state for all scenarios that would require abandonment in order to avoid core damage. The NRC has expressed concern that insufficient evaluation may have been performed to justify the use of this single value given the plant-specific and scenario specific aspects of the actions required in order to achieve this condition. Section 5.1.3 of NUREG-1921 briefly discusses when it might be appropriate to model a single HFE for the complete set of all operator actions necessary to provide safe shutdown of the plant from outside of the MCR with an overall human error probability (HEP) of 0.1 once feasibility is confirmed. According to NUREG-1921, such an approach may be sufficient if all operator actions have been shown to be feasible and MCR abandonment is shown to be not risk significant.

Historically, the approach of applying a 0.1 to all scenarios is a holdover from the simplified modeling of the IPEEE era. Within the range of plant-specific scenarios, there are likely to be scenarios where the 0.1 HEP is bounding, scenarios where the 0.1 HEP is appropriate, and scenarios where the 0.1 HEP is non-conservative.

This latter result is the root of the NRC concern, and further they have concerns that the 0.1 HEP ~~approach from contained in~~ Section 5.1.3 of NUREG-1921<sup>1</sup> is lower than the values that would be obtained by applying the scoping approach from Section 5.2 of NUREG-1921. NRC objects to the use of the 0.1 for MCR abandonment without further justification.

**Potentially relevant existing FAQ numbers:**

None.

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**Response Section:**

**Proposed resolution of FAQ and the basis for the proposal:**

**1.0 Introduction**

The analysis of fires inside the main control room ((MCR) involves the sequential examination of individual fire scenarios. Each scenario first considers the success or failure of fire suppression. Successful fire suppression leads to limited habitability issues and does not lead to a demand for abandonment. This type of scenario is not addressed in this FAQ and can be modeled with typical Fire HRA considerations as described in NUREG-1921.

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<sup>1</sup> [Page 5-8 Table 5-1 and footnote on page 5-7.](#)

**Comment [O4]:** This approach is NOT from NUREG-1921. Several authors didn't want this approach to be included. The only reason it was included was because it was a holdover from the NUREG/CR-6850 screening approach.

**Comment [p5]:** Regardless of the reason why this appears in NUREG-1921, or where it came from originally, it is included in NUREG-1921 in the screening section. Page 5-8 Table 5-1 and with discussion on page 5-7 in a footnote. The reference is correct.

**Comment [p6]:** Since this statement is intended to express a summary of NRC's concerns, we have accepted NRC's edits.

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MCR fires that are not suppressed are further examined in the context of resulting fire damage (both fire-induced initiating event as well as fire damage to SSCs). In this latter case, the impact of the unsuppressed fire on plant systems and functions is increased, and at some point control room habitability is threatened. Those fires that lead to a demand for MCR abandonment are addressed in this FAQ.

For each scenario leading to a demand for abandonment, the PRA Standard requires consideration of human reliability cognition and manipulation. In particular, for LOH control room abandonment, given the successful decision to abandon, failure to successfully achieve a state that avoids core damage, which consists of

- o The decision to abandon (as previously discussed, this is a given for LOH, and so is assumed to succeed)
- o Operator failure to successfully execute the necessary actions, including the cognitive component. The actions needed for the transfer of control from the MCR to the local station(s) where shutdown actions will be performed
- o The actions at the local stations associated with successful shutdown, including any required supervisory coordination and communication
- o Failure of the functioning of the equipment required to successfully shutdown.

For LOH, there is no contribution from the failure to diagnose and decide to abandon the control room in time to execute a successful shutdown (i.e., the first bullet is considered to always be successful).

Appropriate modeling for each of these is outlined in Figure 1. The process steps in the flow charts are described in the text below, which describe the various approaches and options. The “approaches” address differences in the human reliability analysis modeling and the “options” describe different ways to incorporate the resulting human failure event into the Fire PRA model.

**Comment [O7]:** I realize that we're talking about the PRA Standard here. However, the NRC differs in thinking that there are three aspects: 1) the decision, 2) actions needed for the switchover, and 3) all diagnosis (including supervisory coordination & communications) & actions associated with successful shutdown.

**Comment [p8]:** This has been clarified

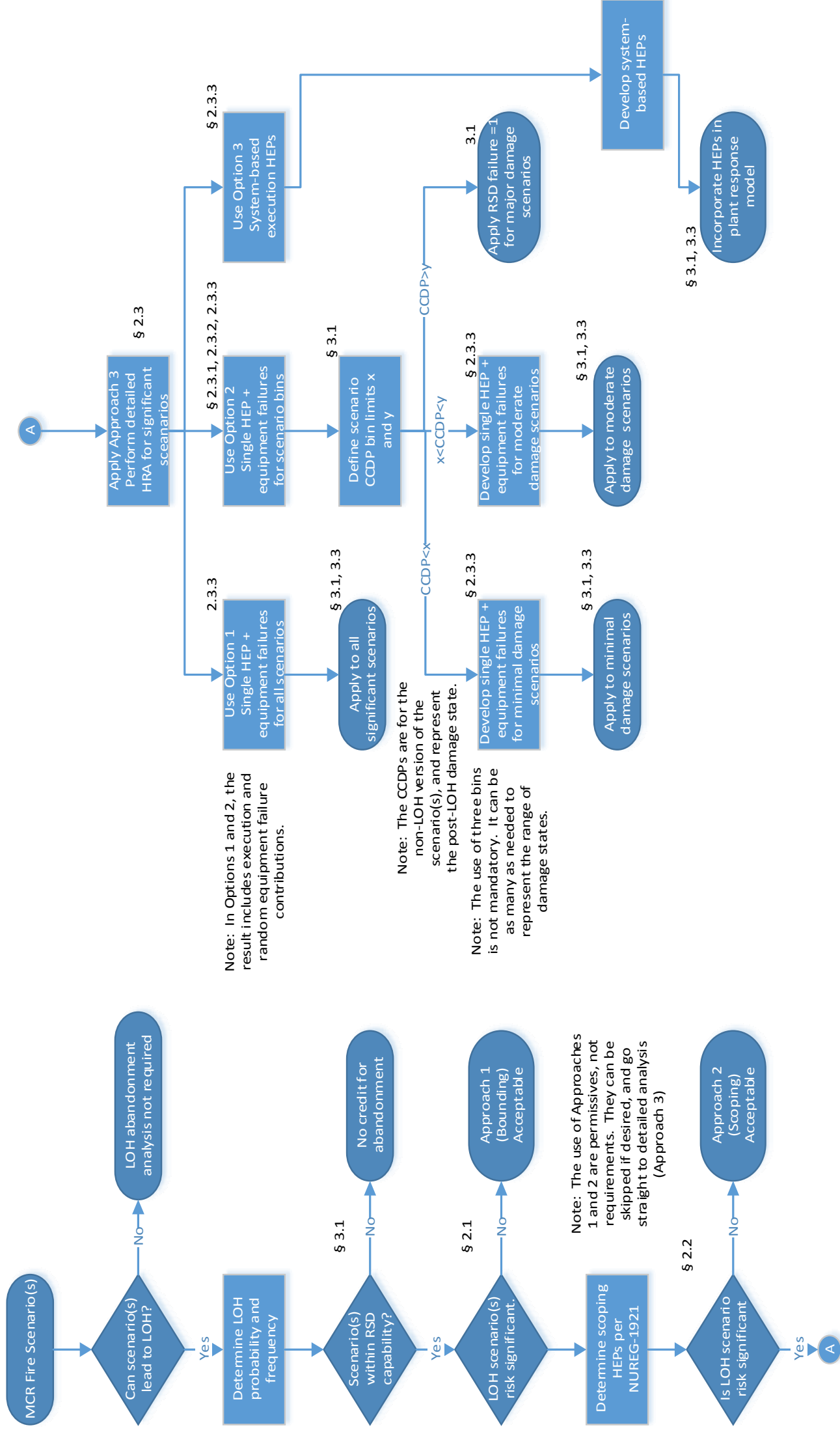
**Comment [O9]:** We need to have discussion regarding the figure. It's not clear first of all, why a single HEP constitutes a detailed HRA analysis. We need to understand the rationale here. Secondly, the discussion under Option 2 of Approach 3 seems to be overblown. We do not understand the need for such a complex addition to the table.

**Comment [p10]:** Further clarification is added later in the text. Summary of rationale is in the comments added below.

**Comment [p11]:** Rationale for option 1. If we accept the concept that scenarios can be binned and an HEP based on the worst case in a bin, then this simply address the case where there is only one bin (all LOH scenarios) and the worst case is used for the HEP. It is detailed because it is based on a plant-specific modeling of the procedures and actions required for that scenario.

**Comment [p12]:** Rationale for option 2. This addresses the option for binning scenarios based on CCDP bins. This was an approach that was used for some plants and that NRC said was acceptable. Including it in the FAQ establishes it as acceptable and provides guidance for applying it acceptably.

Figure 1 - Flow Chart for Abandonment Due to Loss of Habitability (LOH)



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The various acceptable modeling approaches are discussed in detail in this FAQ. Because there are a variety of ways to quantify the HEP and a variety of ways to incorporate the HFE into the Fire PRA, not all modeling combinations are detailed in this FAQ. ~~One example of an acceptable approach that is not described further is for non-risk significant HFEs to be applied to MCR scenarios using the Option 1 systems modeling approach without using the Option 1 quantification approach.~~

It should be noted that equipment failures that preclude successful execution also need to be considered in the analysis. As with the HRA aspects, there is more than one approach to modeling this, ~~and these are also discussed in the FAQ but there is nothing new or unique about it with regard to MCR abandonment and so it is only mentioned in passing in the FAQ for completeness.~~ The flow chart is applied to each fire scenario (or group of similar scenarios) that occurs in the control room.

**2.0 Assessment of Credit for Abandonment (Remote Shutdown (RSD))**

This section discusses various options for determining the amount of credit to apply to abandonment scenarios. The three approaches discussed provide an increasing level of detail and realism, permitting simplified approaches to be applied to scenarios that are not risk significant.

**2.1 Approach 1 - Bounding Approach**

Loss of habitability creates conditions that result in scenarios where it is physically impossible for the operators to remain in the MCR without risking serious physical harm. NUREG/CR-6850 defines the conditions that would force abandonment. There have been no issues raised with regard to its application. Based on that guidance, it is concluded that it is not credible that the operators will remain in the MCR under such conditions. Therefore, the probability of abandonment due to loss of habitability is not based on the HRA, but rather developed by establishing and justifying the fire conditions that would force abandonment (e.g., smoke, heat) and using probabilistic fire modeling techniques to assess the conditional probability that MCR fire scenarios would lead to abandonment due to loss of habitability. However, it is still possible that the CDF/LERF associated with LOH is so small at a particular plant that it does not contribute significantly to the overall fire risk. If this is the case, then the use of the bounding approach is justified even though it is conservative since the conservatism does not affect the fire risk insights and conclusions from the PRA. As shown on the flow chart, this is determined by combining the frequency of each MCR scenario with the conditional probability that the scenario leads to the environmental conditions that would cause the loss of habitability to occur.

The use of this approach for abandonment due to LOH is bounding in the sense that one would expect that it would yield the highest value of CDF and LERF from LOH fire scenarios.

**Comment [J13]:** What does this mean?

**Comment [p14]:** Discussion unnecessary. Has been deleted.

**Comment [O15]:** I would recommend including this in the FAQ only if there's something new or unique about the treatment for MCR Abandonment, as opposed to the rest of the fire PRA.

**Comment [p16]:** Clarification added

**Comment [O17]:** A discussion of feasibility assessment for abandonment should be included somewhere; maybe here or in a separate section.

**Comment [p18]:** The requirement for the performance of a feasibility assessment is not an area of contention between industry and NRC, nor is the approach to performing the feasibility assessment. No further guidance in this area is required. For completeness, the need for the feasibility assessment has been added to the section on "Circumstances requiring interpretation or new guidance" and it is stated as not treated in the FAQ, for the reasons stated above.

When applied to abandonment due to LOH, the implications to the results of the Fire PRA must be considered. This would be considered a screening-type approach for the MCR abandonment aspects of the HRA, and so would be expected only to be used in scenarios that are not risk-significant.

## 2.2 Approach 2 - Screening/Scoping Approach

**ALL OF THE MATERIAL HIGHLIGHTED IN YELLOW WILL BE REPLACED WITH A NEW APPROACH, CURRENTLY SUBJECT OF A SEPARATE WHITE PAPER, ONCE AGREED TO WITH NRC.**

One of the fundamental modeling questions that has been raised by the NRC is whether the use of the NUREG-1921 screening approach and 0.1 HEP is representative for all MCR evacuation scenarios. The NRC has suggested using the scoping flowcharts presented in section 5.2.7 and 5.2.8 of NUREG-1921 to provide a more detailed HRA analysis. Since these scoping flowcharts generally produce HEPs of 0.2 and 0.4 if there are any actions needed in the first 30 minutes, and even higher values in cases where the time margin is limited, time is an important parameter that must be considered when using the scoping approach and requires performing a check to look for time critical actions where the time required is close to the time available. While the general HRA process and associated HRA methods address this, delays in processing multiple cues and deciding to abandon can impose a significant change to the timelines. This challenge or change is unique to MCR abandonment.

Many plants have used the screening approach for the detailed human reliability analysis (HRA) quantification per Section 5.1.3 of NUREG-1921. Because the screening approach yields values lower than the scoping approach, the screening approach is susceptible to additional scrutiny. However, before jumping to a detailed HRA approach, it should be pointed out that if the MCR Abandonment scenarios developed from the scoping approach are not risk-significant (as defined in the combined PRA Standard) then a bounding, screening or scoping approach is appropriate and can be deemed as achieving an overall assessment of CC-II for the MCR abandonment evaluation (since risk-significant scenarios are not impacted). Similarly, if this is not the case, then leaving the scoping approach in the risk-significant scenarios would result in a CC-I finding for one or more SRs.

In this approach, the Fire PRA should develop the remote shutdown failure probability for main control room (MCR) evacuation scenarios by summing the contribution of hardware failures with the failure probability for operator actions. The hardware failures can be quantified separately (typically as a cutset equation) for each scenario or for a bounding scenario, accounting for the fire-induced damage to equipment. The set of all operator actions necessary to provide safe shutdown of the plant from outside of the MCR can be modeled as a single human failure event with an overall human error probability (HEP) as established by the screening/scoping approach.

**Comment [O19]:** NRC will not comment on the yellow material since it is to be replaced. However, note that 1921 can provide smaller or comparable failure probabilities to 0.1 for transfer/ASD for certain plant configurations.

**Comment [p20]:** The material has been forwarded to NRC as a separate document for further discussion, consisting of a main section and two Attachments with examples.



Once again, the question is whether, with these screening/scoping values applied, the CDF/LERF associated with LOH scenarios is so small that it does not contribute significantly to the overall fire risk. If this is the case, then the use of the screening/scoping approach is justified even if it is conservative since the conservatism does not affect the fire risk insights and conclusions from the PRA. As shown on the LOH flow chart, this is determined by applying the scoping HEP to the scenario(s) frequency of each MCR scenario that leads to LOH and asking if the contribution is significant. If the contribution of the scenario(s) to CDF/LERF using a screening/scoping HEP is not significant, then the use of the screening/scoping approach is acceptable.

**2.3 Approach 3 - Detailed Approach**

There are two levels of approaches to detailed analysis that can be applied. The first approach is to use the concept of “scenario bins” that treat all the scenarios in the bin as having; a single HFE covering all abandonment scenarios in the bin. There are two options for this (these are designated as Option 1 and Option 2 for detailed analysis) – either one bin that covers all LOH scenarios or multiple bins that group scenarios by severity. In either case, a detailed HRA is performed using plant specific procedures, features, and PIFs that would bound the conditions resulting from all scenarios in the bin (a “representative scenario”).

The second approach (which has one option, designated as Option 3 for detailed analysis) ~~or develops~~ multiple HFEs to address nuances of the various abandonment scenarios individually (i.e., when applied in the model it will result in scenario-specific results for each individual scenario).

Note that there is nothing that prohibits performing a detailed HRA for each of the LOH scenarios, even if the bounding or scoping approach would be sufficient. Theis application of bounding or screening/scoping values to non-significant scenarios is a permissive, not a requirement. This is noted on the flow chart.

Regardless of how the detailed HRA is implemented, it is extremely important to perform a check to look for time critical actions where the time required is close to the time available. While the general HRA process and associated HRA methods address this, the delays in processing multiple cues and deciding to abandon can impose a significant change to the timelines. This challenge or change is unique to MCR abandonment.

**2.3.1 Cognitive Failure - Failure to Abandon the Control Room in Time to Execute a Successful Shutdown**

For abandonment due to loss of habitability it is not necessary to consider the possibility that the control room will not be abandoned. These conditions will result in scenarios where it is physically impossible for the operators to remain in the MCR

**Comment [J21]:** Don't get this sentence

**Comment [p22]:** It means that if the screening [sic] HEP does not significantly affect the CDF/LERF, then it is OK to use it and not perform detailed analysis. This has been clarified.

**Comment [O23]:** Again, we're not sure of the how behind developing the single HFE. Need to understand as discussed earlier with regards to the figure. The PRA Standard says that detailed analysis needs to address the scenario specific aspects that influence operator actions.

**Comment [p24]:** Clarification has been added based on our prior discussions.

**Comment [J25]:** Deciding to abandon is not an issue in LOH. What is the point here?

**Comment [p26]:** Agreed. This should have been delated when we split out LOC and LOH.

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without risking serious physical harm. In general, plant procedures and training provide specific cues to indicate an abandonment condition. Further, NUREG/CR-6850 defines the conditions that would force abandonment. There have been no issues raised with regard to its application. Based on this NUREG/CR-6850 that guidance, it is concluded that it is not credible that the operators will remain in the MCR under such conditions. Therefore, the probability of abandonment due to loss of habitability is not based on the HRA, but rather developed by establishing and justifying the fire conditions that would force abandonment (e.g., smoke, heat) and using probabilistic fire modeling techniques to assess the conditional probability that MCR fire scenarios would lead to abandonment due to loss of habitability. Thus is why, the detailed HRA section of the flow chart does not mention assessment of a cognitive HEP for the choice to abandon the MCR under LOH conditions.

2.3.2 Execution Failure - Given abandonment, failure to successfully achieve a state that avoids core damage

This is the execution aspect of the abandonment action. The human failure event associated with this action consists of both failures to perform the proper actions and also equipment failures that prevent the operators from being successful in avoiding core damage using the abandonment procedures.

Operator Execution Action Categories. The operator actions for each scenario can generally be grouped into three categories:

- Category 1 – Actions Needed for All Scenarios. This category of actions consists of those required to transfer control from the MCR to the RSD location(s), to restore decay heat removal (such as AFW in a PWR, torus cooling in a BWR), injection (such as CVCS in a PWR, RCIC in a BWR) and associated support systems; which are the minimum set of systems necessary to provide safe shutdown. Failure to provide any of these actions is modeled in the PRA as leading to core uncover. These actions are required for all control room evacuation scenarios, can be evaluated using detailed HRA, and then can be incorporated back into the Fire PRA as a single basic event or as multiple events (see options below). The detailed analysis of these execution errors can be accomplished following the NUREG-1921 guidelines.
- Category 2 – Actions Needed for Some Scenarios. This category of actions consists of those that may be required in order to support the Category 1 actions, but in certain scenarios may not be available. For example, there may be a need to restore power to a bus in order to restore AFW. It would be expected in this case that once the power had been restored to the bus, the AFW actions would still be required (that is, AFW would not simply automatically start when power was restored). However, some scenarios may not be accompanied by failure of the bus power, and so failing to perform

**Comment [O27]:** This statement is too strong & I'm not certain how generic it is. Procedural and training support for abandonment for LOH is not strong or clear & we shouldn't say otherwise.

**Comment [p28]:** We can soften this.

**Comment [O29]:** I disagree with the implication that procedures or training provide "guidance" on MCR abandonment for LOH.

**Comment [p30]:** In this case we are referring to the guidance in 6850 regarding conditions that force abandonment, not the procedures. This can be clarified.

**Comment [O31]:** Just because a decision to abandonment the MCR has been made doesn't mean all decision-making is over. A cognitive contribution to operator failure still needs to be addressed for remaining actions.

**Comment [p32]:** We will need to discuss this further in person to work out the nuances.

**Comment [O33]:** Where are the actions to successfully accomplish switching control from MCR to elsewhere?

**Comment [p34]:** They are considered as a subset of the execution actions. They would be Category 1 actions below, and this has been clarified.

**Comment [O35]:** We don't understand how these categories can be used as there are other important factors as we've discussed in our meetings. Thus, we don't think there's an advantage to formalizing this strategy in the FAQ.

**Comment [p36]:** We did provide additional explanation of this in a subsequent version of the FAQ. We explain that this serves two purposes – on to make sure the compilation of the actions required is complete, and two is as a potential basis for scenario binning. That material has been incorporated again here.

**Comment [O37]:** Are you absolutely certain there is no diagnosis at all?

**Comment [p38]:** We do expect that at this point the operators will be following step-by-step procedures with minimal cognitive elements. However, we should discuss any nuances and reach agreement when we meet.

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those actions would not result in failure to restore AFW. As with Category 1 actions, these can be evaluated using detailed HRA, and then can be incorporated back into the Fire PRA as part of the single basic event or as multiple events.

- Category 3 – Additional Actions Needed to Mitigate Spurious Actuations. This category of actions is modeled in addition to the actions taken for all scenarios (Category 1). This category consists of actions required to mitigate spurious control signals that cause equipment actuation or inability to place equipment in a desired state, and so that ~~restore~~ the RCS and SG boundaries can be restored to a state where the AFW and CVCS systems can provide for safe shutdown. This category of actions for PWRs includes the operator tripping reactor coolant pump ~~trip~~, isolation of RCS boundary valves (pressurizer PORV, RCS head vent, pressurizer vent, and RCS letdown), isolation of the SG's (closure of open MSIVs, closure of open SG-ADVs, and closure of open SG blowdown valves), and termination of spurious safety injection. An example action for BWRs would be isolation of spurious SRVs. These actions are required only when fire damage causes a spurious event which must be terminated. The HFE's for these events are modeled in the logic along with the component failure modeling the spurious event. The detailed analysis of these execution errors can be accomplished following the NUREG-1921 guidelines.

The purpose of the three categories is to assure completeness in the consideration of the the execution actions evaluated, and to provide for effective binning of scenarios by their intricacy, should such binning be desired. That is, the extent of the damage caused by the scenario can be expressed in terms of the categories of actions required to be executed in response, and thus HEPs can be developed that consider the extent of damage. This is explained further below in the detailed HRA options.

~~Therefore, each action required by the abandonment procedure should be considered.~~

### 2.3.3 Performing the Detailed Analysis

There are three options that can be used to perform the detailed analysis in the FPRA.

- Option 1 - The first option would be to model the failure to achieve successful shutdown as a ~~single one~~ -HFE for a plant-specific representative scenario that would envelope all abandonment scenarios for which remote shutdown credit is to be applied, with all the execution actions required for shutdown

**Comment [J39]:** What is the mechanism that causes the RCP to spuriously trip?

**Comment [p40]:** This does not refer to spurious trip. This refers to the operator action to trip them if they are spuriously still running. Have tried to clarify.

**Comment [O41]:** Prior comment on detailed analysis. Need to understand how you're doing this. Are you estimating HEPs for scenarios and somehow rolling them up into a single value? Or is the intent to establish a single HEP in another fashion? How are equipment failures treated?

**Comment [p42]:** Response discussed previously. Regarding equipment, it was discussed that equipment failure probability needed to be accounted for. This is stated in the last sentence of this section.

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analyzed as part of that HFE.<sup>2</sup> That is, it is acceptable to develop ~~a single one~~ HEP, developed from a detailed human reliability analysis, that assumes that all the actions required for shutdown are always needed for all scenarios. Because a single value will be used for all the scenarios, the HEP must represent the most intricate abandonment scenario (the abandonment scenario that involves the loss of the most equipment and thus the execution of the most actions, and under the least favorable PIFs, of any scenario that will be credited). In this case, all of the Category 1, 2, and 3 actions would be included in the single HEP, and applied to all abandonment scenarios. This would be somewhat conservative, but not overly so. When using Option 1, developing the HEP is only part of the modeling. While the HRA is detailed, the logic modeling is simplified by applying the failure as a single event leading to core damage. For this reason, it is necessary that the overall probability of core damage encompass both the probability of human failure in the execution steps and the failure probability of the equipment. Therefore, for each execution activity the random failure probability of the required equipment needs to be added to the HEP, unless it can be shown numerically that the contribution is insignificant.

~~This option would be most useful to those plants that have already chosen to use 0.1 as the generic failure probability for abandonment. The information that is gathered in order to demonstrate feasibility provides sufficient basis to perform a reasonably detailed HRA in order to develop an HEP to either confirm the applicability of the 0.1 or to replace it with an appropriate value.~~

- Option 2 - It is noted that in reality different scenarios may result in only a subset of the actions being required (even though there is a loss of ~~habitability~~ control, a particular system may not fail, and so the actions taken to recover that system may not be required for that specific scenario). It is therefore acceptable to develop different "flavors" of ~~the single~~ HEP, developed from a detailed human reliability analysis, with scenario-specific considerations. Under this option, the scenarios would be "binned" into groups where ~~a single one~~ execution HEP could be applied to the entire bin.

The LOH situation would have a wide range of damage conditions to consider, since in fact LOH could result from a fire in a relatively unimportant area of the control room (that is, minimal impact on the functions required to successfully shut down) all the way to areas where the damage is very significant in terms of lost systems, functions, and indication. Thus, the difficulty in achieving successful shutdown once the control room was abandoned would vary greatly. Because of this, in applying option 2, a useful

<sup>2</sup> Note that this is unlikely to be all actions taken during abandonment. It is expected that some actions that are taken are to protect equipment, and failure to perform those actions would not result in core damage. Therefore, these would not need to be considered in the analysis.

**Comment [p43]:** We agreed to delete this in previous discussions, as it was inconsistent with the new approach under section 2.2.

**Comment [O44]:** Why are we talking about LOC?

**Comment [p45]:** Sorry. This should say habitability.

**Comment [J46]:** Again, how is the single HEP developed? CCDP?

**Comment [p47]:** As stated previously, it is based on the worst case scenario for the bin.

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surrogate for the extent of damage (and thus the difficulty in shutdown) is the CCDP of the equivalent scenario that does not lead to LOH. This is shown under Option 2 on the flow chart. In this case, the HEP is developed by examining the scenarios in each bin and developing the HEP based on the most intricate scenario in the bin. In this case it is expected that it would not be necessary to include all of the Category 1, 2, and 3 actions for each bin. For example, the most intricate scenario in the lowest CCDP bin would not be expected to include spurious operations that would need to be recovered, and so Category 3 actions would not be part of the HEP for this scenario bin (although this still would need to be confirmed). Again, this would also assume the least favorable PIFs of any scenario in the bin. Further discussion of theThe application of this method is discussed later in this FAQ, in the discussion of application guidance.

As with Option 1, developing the HEP is only part of the modeling. While in this option there are multiple versions of the HRA modeling, the logic modeling is still simplified by applying the failure as a single event leading to core damage to each scenario. For this reason, it is necessary that the overall probability of core damage for each variation encompass both the probability of human failure in the execution steps and the failure probability of the equipment. Therefore, for each execution activity the random failure probability of the required equipment needs to be added to the HEP.

- Option 3 - Another way to address scenario-specific considerations would be to break down the actions in the abandonment procedure by system/function and have a separate HFE for failing to recover each system/function. This approach would address the case where, for a given scenario, a system did not fail due to fire. If the system did not fail, the failure of the action would not fail the system, and this would be handled in the logic model. The model would have to account for fire-induced failures that were not recoverable, so that the HFE was not improperly credited. In this modeling, the concept of the category 1, 2, and 3 actions is not as necessary because the specific actions required by the scenario are directly included in the model at the systems level and applied when the fire fails the system for the given abandonment scenario. However, the evaluation of dependency (in particular communications, coordination and staffing) takes on a greater importance because it involves dependence between actions that are spread out through the model whereas for Options 1 and 2 the dependency is mostly internal to the integrated HFE.

It is also necessary to determine that all of the actions will work if properly executed, so the analysis needs to account for fire damage that would fail the action regardless of what the operators do, and not credit the remote shutdown in those cases.

### 3.0 Application Guidance

Comment [O48]: What about cognition?

Comment [p49]: Response previously discussed.

This section provides additional guidance related to the implementation of the abandonment credit in the FPRA model.

### **3.1 Guidance on limitations to the application of abandonment credit**

Most remote shutdown capabilities are designed to achieve successful shutdown only under general transient conditions and may not have considered the impact of multiple spurious operations on the equipment relied upon for remote shutdown. Therefore, in general, no credit for remote shutdown should be applied for conditions such as ATWS, LOCA, interfacing systems LOCA, or main steamline break conditions (e.g., unisolated stuck open atmospheric relief valves for PWRs) or in cases where fire damage (e.g., multiple spurious operations) could result in unrecoverable loss of the remote shutdown capability. Therefore, if the fire causes these conditions and they are not recoverable as part of the abandonment procedure, then core damage should be assumed. An assessment of the conditions that would preclude success would be determined for the specific plant, and the model developed to reflect that abandonment credit could not be applied to fire scenarios that caused these conditions. This is represented on the flow chart by the decision diamond labeled "Scenario(s) within RSD capability?" where an answer of No leads to the terminus labeled "No credit for abandonment."

Example: Three plants have the following situations under the condition of a fire induced PORV LOCA (a fire scenario that causes spurious opening of a PORV along with failure of a block valve). None of them can reach a safe condition from outside the control room with the LOCA in progress.

- Plant A – The design of the circuit is such that there is no action that can be taken to clear the fault and allow the PORV to reclose. For the LOH scenarios that cause this condition, no credit can be given for shutdown from outside the control room (core damage will occur).
- Plant B – The design of the circuit is such that it is possible to pull a fuse to clear the fault and allow the PORV to reclose, but that action is not in any procedure. For the LOH scenarios that cause this condition, no credit can be given for shutdown from outside the control room (core damage will occur), but if the plant modifies the procedure to include pulling the fuses and it is determined to be feasible, then credit can be applied.
- Plant C – The circuit includes a disconnect switch that will always clear the fault and allow the PORV to reclose, and the action to throw the disconnect switch is part of the abandonment procedure. For the LOH scenarios that cause this condition, credit can be given for shutdown from outside the control room.

### **3.2 Guidance on the use of detailed HRA option 2 - binning**

**Comment [O50]:** There is no discussion on option 3. Should provide a section to simply say it's not being discussed in this FAQ.

**Comment [p51]:** We can do that. However, it should be noted that the reason it is not discussed is because we do not believe further guidance is required for Option 3 because there are no simplifications that need to be agreed on.

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Any of the execution failure analysis options previously discussed can be applied to failure during abandonment due to loss of habitability. However, the use of Option 2 does have certain advantages for the abandonment due to loss of habitability case. The various scenarios that would cause abandonment due to loss of habitability can result in widely different levels of plant damage, from almost no effect on key safety systems up to and including a loss of control. The extent of fire damage is indicated by the non-abandonment CCDP of the scenario. The failure of execution could therefore be based on CCDP that is obtained before taking the abandonment credit. The higher the CCDP, the more actions that would be required upon leaving the control room. For example, the scenarios can be placed in three bins, and then three shutdown execution failure HEPs used. The selection of the three values would be based on Option 2 of the execution failure analysis approach previously discussed.

Calculated CCDP (non-abandonment)	Abandonment CCDP used for risk quantification	Basis for CCDP used
CCDP < x	$z_1$	A CCDP of less than "x" is consistent with a less challenging event that would not have time critical actions.
$y > \text{CCDP} \geq x$	$z_2$	A CCDP of "x" or greater but not greater than "y" indicates a more significant consequence associated with challenges caused by the fire.
CCDP $\geq y$	1.0	A CCDP of "y" or greater indicates significant consequences with the potential for time critical action. The treatment of such events given abandonment of the MCR could also be expected to have large uncertainty. A conservative treatment assumes such events are not recoverable.

**Comment [J52]:** The table seems like overkill. Isn't the point to map sequences on MCR abandonment, and to use the most restrictive scenario from the bin for quantification? What else is the table conveying.

**Comment [p53]:** Again, this approach was used by some plants and was found agreeable by NRC. We would like to document that.

The values for x and y would be specified on a plant specific basis by reviewing the scenario CCDP results for the non-abandonment MCR scenarios and identifying logical break points for damage. This would result in the scenarios each being assigned to a bin. The values for  $z_1$  and  $z_2$  would be based on the most restrictive scenario in each bin. The specific values for  $z_1$  and  $z_2$  will be plant specific based on the results of the pre-abandonment CCDPs and an assessment of where there are natural break points in the CCDPs and the associated severity of damage to plant systems resulting from the scenarios. For the top bin, it is clear that the most restrictive scenario would be non-recoverable, so 1.0 would be used for this bin.

**Comment [J54]:** How is the fact that each bin contains many scenarios factored into this surrogate CCDP?

**Comment [p55]:** Not sure what you mean by surrogate CCDP?

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**Comment [O56]:** I'm afraid that this part of the approach is confusing to me, especially without explicitly defining  $z_1$  &  $z_2$ .

**Comment [p57]:** It is not possible to establish specific values for  $z_1$  and  $z_2$ . They would be plant specific, based on the worst case scenario in the bin.

Note that the selection of only three bins, as discussed above and shown on the flow chart, is only an example. Should it be determined through examination of the LOH scenarios at a given plant that there are a greater number of damage states that could be considered, then additional damage states could be defined. One

~~approach to this would be to select the CCDP range for each bin based on what action categories would be needed for each CCDP bin (see section 2.3.2).~~

~~This approach could also be applied by using fire location in the MCR as opposed to CCDP (i.e., which panels are affected and the associated damage to plant systems).~~

### ~~3.3 Dependency~~

~~As some of the cutsets leading to loss of control due to fire may contain human failure events, dependency analysis needs to be considered in the application of credit for abandonment. For example, in a PWR, if the fire causes a loss of secondary heat removal and the reason that secondary heat removal is not recovered is because of a failure to recover AFW (i.e., the cutset includes a HFE for failure to recover an AFW pump train), then the decision on whether to abandon would be affected by the operator's failure to diagnose that there is a loss of all secondary heat removal. This would influence the decision to abandon, and would therefore need to be evaluated and accounted for in the dependency analysis.~~

~~If appropriate, provide proposed rewording of guidance for inclusion in the next Revision:~~

~~Not applicable. There is no current guidance beyond RG 1.200.~~

**Comment [J58]:** Don't understand. Fire location and CCDP are separate items, one does not imply the other.

**Comment [p59]:** Yes, they can be. For example, MCR fires that affect back panels that contain no PRA equipment would have about the same CCDP. Further bins could be applied in similar manner.

**Comment [J60]:** LOH is rather well defined. Since this sentence refers to a function, are you discussing LOC, which is out of scope?

**Comment [p61]:** Yes. This should have been deleted when LOC and LOH were split.

**Comment [p62]:** This dependency discussion pertains to special considerations in loss of control diagnosis, and is not relevant to LOH. A discussion of execution dependency has been added to the detailed HRA.