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SPAR-H Step-by-Step Guidance

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April M. Whaley
Dana L. Kelly
Ronald L. Boring
William J. Galyean

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Idaho National Laboratory

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April M. Whaley[a*], Dana L. Kelly[a], Ronald L. Boring[a], William J. Galyean[a]
[a]Idaho National Laboratory, Idaho Falls, ID, USA

Abstract: Guidance was developed recently at Idaho National Laboratory for the US Nuclear Regulatory Commission on the use of the Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method for quantifying Human Failure Events (HFEs). This work was done to address SPAR-H user needs, specifically requests for additional guidance on the proper application of various aspects of the methodology. This paper overviews the steps of the SPAR-H analysis process and highlights some of the most important insights gained during the development of the step-by-step directions. This supplemental guidance for analysts is applicable when plant-specific information is available, and goes beyond the general guidance provided in existing SPAR-H documentation. While written with event assessments in mind, this guidance may be informative to other typical applications of SPAR-H. The steps highlighted in this paper are: Step-1, Categorize the HFE as Diagnosis and/or Action; Step-2, Rate the Performance Shaping Factors; Step-3, Calculate PSF-Modified HEP; Step-4, Account for Dependence, and; Step-5, Minimum Cutoff Value.

Keywords: SPAR-H, HRA, user guidance

1. INTRODUCTION

This paper excerpts and summarizes information provided in Whaley et al. (2011)[1], an Idaho National Laboratory (INL) technical report that provides step-by-step guidance on the use of the Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method for quantifying Human Failure Events (HFEs). This document provides supplemental guidance for analysts when plant-specific information is available (e.g., event and condition assessments), which goes beyond the general guidance provided in existing SPAR-H documentation. This guidance was developed with the intent of addressing user questions about proper application of the method; while written with event assessments in mind, this guidance may be informative to other typical applications of SPAR-H.

The guidance that follows is provided to aid an analyst in filling-out the SPAR-H worksheets provided in NUREG/CR-6883 (Gertman, Blackman, Marble, Byers, & Smith, 2005) that are used to estimate human error probabilities (HEPs). SPAR-H is a method for HFE quantification. It does not provide guidance on how to identify or model HFEs, or other aspects of the qualitative HRA needed to support quantification. Therefore, SPAR-H starts with the assumption that the qualitative analysis has already been conducted, and the HFE to be quantified has already been identified and is adequately represented in the risk model.

This paper provides guidance on five steps for implementing SPAR-H:

1. Categorize the HFE as Diagnosis and/or Action;
2. Rate the Performance Shaping Factors (PSFs; this section includes guidance on PSF level assignment);
3. Calculate PSF-Modified HEP;
4. Account for Dependence (discussed in Whaley & Kelly, these proceedings); and,
5. Minimum Cutoff Value.

2. STEP 1: CATEGORIZE THE HFE AS DIAGNOSIS AND/OR ACTION

In the context of SPAR-H, HFEs are categorized as either Diagnosis tasks or Action tasks (or combined Diagnosis and Action). Diagnosis for the purpose of SPAR-H quantification refers to the entire spectrum of cognitive processing, from the very complex process of interpreting information and formulating an understanding of a situation, to the very simple process of just deciding to act.

[1] The Whaley et al. (2011) SPAR-H Step-by-Step Guidance technical report is available for download from the INL website at http://www.osti.gov/energycitations/product.biblio.jsp?query_id=1&page=0&osti_id=1027888.

The bases for the nominal SPAR-H HEP values and for the PSF modifier values are discussed in detail in Boring & Blackman (2007). They explain that the nominal HEP value for the "Action" part of the SPAR-H worksheets (0.001) is based on error rates for simple action implementation, such as pressing a button or turning a dial, and simple slips or lapses in the taxonomy used by Reason (1990). Furthermore, "Diagnosis" in SPAR-H is intended to refer to cognitive processing and not solely to diagnosis, per se. Most HFEs in a PRA involve much more cognition than merely pushing a switch; therefore it is not appropriate to routinely exclude the Diagnosis component from HFE quantification. A case where the cognitive aspect is modeled as a separate HFE and only the execution is being considered is an obvious example of when it is appropriate to exclude Diagnosis from an HFE. Otherwise, there needs to be a strong justification that the HFE involves no cognitive activity beyond simple action implementation if an analyst wishes to exclude Diagnosis from the HFE.

There are very few situations where a Diagnosis (again, referring to cognitive processing) and an Action are not linked somehow. Action rarely occurs without Diagnosis, but it might be possible to have a Diagnosis that is not followed by an Action. Really the only question here is: is the Diagnosis represented in the HRA as a separate HFE, or is it combined with the Action part into a single-composite HFE?

Therefore, the default modeling in SPAR-H should include both Diagnosis (cognitive processing) and Action (execution). Justification is needed to eliminate one of these elements. This is consistent with the *Good Practices for HRA* (NUREG-1792; Kolaczkowski, Lois, Forester, & Cooper, 2005), which states that both screening and detailed quantification should include both Diagnosis and Execution components, unless the qualitative HRA "indicate(s) that one of these failure modes predominates the other in such a way that the effect of only one failure needs to be quantified."

3. STEP 2: RATE THE PERFORMANCE SHAPING FACTORS

Once the HFE has been categorized, the next step is for the analyst to identify the salient performance drivers, both positive and negative, based on the supporting qualitative analysis, and then rate the eight SPAR-H PSFs accordingly. Each PSF needs to be examined with respect to the context of the HFE to resolve two basic issues. First, is there adequate information to judge the influence of the PSF? Second, does the context for that PSF exert a significant influence on the likelihood of failure for the human operator (i.e., is the PSF a "performance driver")? ONLY those PSFs that have sufficient information to allow an informed judgment and ONLY those PSFs that have been identified as performance drivers should then be evaluated and quantified. Otherwise, the PSF should be assumed to be nominal. If it was not evaluated, or if there was not enough information available to allow an informed judgment about whether it is a performance driver or to choose among the other alternatives, the analyst should set the PSF level at *Insufficient Information* (numerically equivalent to nominal). Also, analysts should consider separately the PSFs for Diagnosis and Action; for example, the context that leads to increased complexity for Diagnosis may not affect complexity for Action.

The following sections overview guidance for each of the PSFs used in SPAR-H.

3.1. Available Time

Available time as a PSF term can be misleading. In the assessment of the Available Time PSF, SPAR-H does not look solely at the amount of time that is available for a task. Rather, it looks at the amount of time available relative to the time required to complete the task. In the existing SPAR-H documentation (Gertman, et al., 2005) this PSF is evaluated by comparing the time required to the time available. Although the exact definitions for the various PSF levels differ between those for Diagnosis and those for Action, both have a basically consistent definition for the nominal level. Namely, nominal is defined as some extra time is available beyond that minimally required. (Nominal time for Diagnosis is actually defined as "on average, there is sufficient time to diagnose the problem," which implies more than the minimum requirement.) Additionally, while it was not part of the original SPAR-H guidance for this PSF, it is useful to include the *time margin* in this discussion, which is the difference between the required time and the available time (US Nuclear Regulatory Commission, 2009). Nominal time includes some small but important time margin over the minimum amount of time required. For Diagnosis, the analyst must recognize that the amount of time needed to make a decision (i.e., formulate a diagnosis) is highly dependent on the individual, and significant variability among operators should be expected. Hence the nominal time should be assessed in terms of how the average operator is estimated to perform. Another way to look at this is to estimate the time needed by a better-than-average operator (i.e., the minimum time required) and add some small but significant time margin for the nominal time. Figure 1 illustrates the different PSF levels graphically using this concept of time margin.

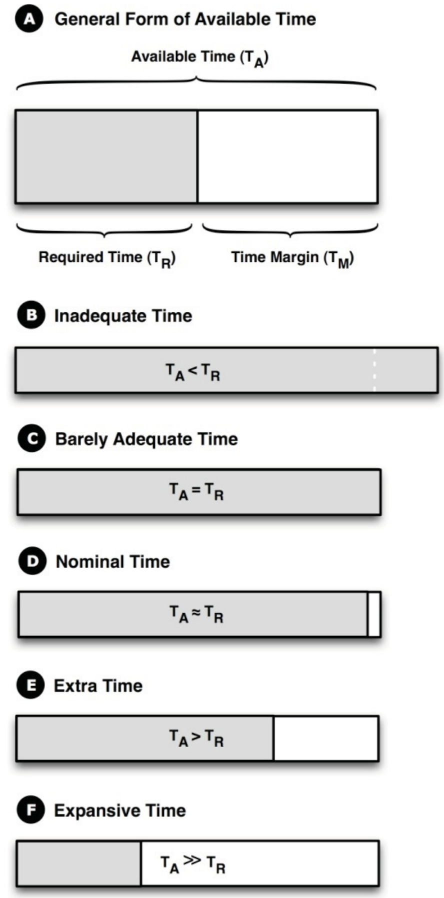

Figure 1. Time available as a function of the time required and the time margin

As depicted in Figure 1, this time margin is simply an alternate way to evaluate the Time Available PSF level assignment in SPAR-H (in addition to *Insufficient Information*):

- *Inadequate Time*—the time margin is negative because less time is available than is required.
- *Barely Adequate Time*—the time margin is zero because the time available equals the time required.
- *Nominal Time*—there is a small time margin because the time available is slightly greater than the time required.
- *Extra Time*—the time margin is greater than zero but less than the time required; the time available is greater than the time required.
- *Expansive Time*—the time margin exceeds the time required; the time available is much greater than the time required.

To apportion the available time between Diagnosis and Action, the analysts should first estimate the nominal time (i.e., the minimum time needed plus some time margin) to perform the action. If there is sufficient time to perform the action, then the Available Time PSF for the Action is judged to be nominal and the remainder of the time is assigned to the Diagnosis part of the event. This might mean that the available time for Diagnosis is not nominal. Additionally, if a time apportionment is done without specifically estimating the time required for Diagnosis, then time available for Diagnosis is either "nominal" or "barely adequate;" no positive adjustment should be used.

See Whaley et al. (2011) for additional discussion of the Available Time PSF.

3.2. Stress/Stressors

Stress as used in SPAR-H specifically refers to the level of undesirable conditions and circumstances that impede the operator in completing a task. Stress can include mental stress, excessive workload, or physical stress such as that imposed by environmental factors. Consequently, stress could manifest on both Diagnosis and Action performance. Environmental factors, often referred to as stressors, such as excessive heat, noise, poor ventilation, or radiation, can induce stress in a person and affect mental or physical performance. It is important to note that the effect of stress on performance is curvilinear—that is, some small amount of stress can enhance performance, and in the context of SPAR-H should be considered nominal, while high and extreme levels of stress will negatively affect human performance. It is the degradation of performance that is the key point when assigning high or extreme stress levels. Typically, this will occur when the context of a situation deviates from what is anticipated (leading to confusion, uncertainty, fear or overloading the capabilities of the human operator). Situations that unfold as expected, even though they might result in some anxiety in the human operators, should be judged nominal. The analyst is cautioned against being too analytical in assigning a stress level. Even if we could predict the specific individual subjected to the context of interest (which we can't), everyone handles stress a little differently. Therefore, the focus for High or Extreme Stress is on those situations outside of what the operator(s) have experienced or trained for.

The levels used for the Stress PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Extreme*—a level of disruptive stress in which the performance of most people will deteriorate drastically, the so-called stress performance cliff. This is likely to occur when the onset of the stressor is sudden and the stressing situation persists for long periods. This level is also associated with the feeling of threat to one's physical well-being, self-esteem, or professional status, and is considered to be qualitatively different from lesser degrees of high stress (e.g., catastrophic failures can result in extreme stress for operating personnel because of the potential for radioactive release).
- *High*—a level of stress higher than the nominal level (e.g., instruments with anomalous readings or unexpected alarms; loud, continuous noise impacts ability to focus attention on the task; the consequences of the task represent a threat to plant safety). This level basically encompasses any situation where there is a perceived threat that can result in significant health or financial consequences (such as loss of the plant).
- *Nominal*—the level of stress that is conducive to good performance. Also, this level should be assigned whenever stress is judged to not be a performance driver.

It is important to note that stress is not independent of other PSFs. Often stress results from limited time, high complexity, poor procedures, poor training, poor work processes, or poor crew dynamics. However, the analyst should make an effort to avoid any "double counting" of specific influencing factors. If time constraints are accounted for in the Available Time PSF, then the effect of time on the Stress/Stressors PSF should be minimized (note that other details of the context, not explicitly accounted for in other PSFs might still need to be accounted for in the Stress/Stressors PSF). While high or extreme stress increases the probability of an error, it does not guarantee failure; people can and have succeeded during high-stress scenarios.

3.3. Complexity

Complexity refers to how difficult the task is to perform in the given context; it considers both the task and the environment. The more difficult the task is to perform, the greater the chance for human error. Similarly, the more ambiguous the task is, the greater the chance for human error. Complexity also considers the mental effort required, such as performing mental calculations, memory requirements, understanding the underlying model of how the system works, and relying on knowledge instead of training, practice or procedures. Complexity can also refer to physical efforts required, such as physical actions that are difficult because of complicated patterns of movements.

In general, a task with greater complexity requires greater skill and comprehension to successfully complete. Multiple variables are usually involved in complex tasks. Concurrent Diagnosis of multiple events and execution of multiple actions at the same time is more complex than diagnosing and responding to single events.

The levels used for the Complexity PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Highly Complex*—very difficult to perform. There is much ambiguity in what needs to be diagnosed or executed. Many variables are involved, with concurrent diagnoses (or actions). For example, an unfamiliar equipment line-up is required that involves defeating interlocks on valves.
- *Moderately Complex*—somewhat difficult to perform. There is some ambiguity in what needs to be diagnosed or executed. Several variables are involved, perhaps with some concurrent diagnoses (or actions). For example, an atypical system startup is executed requiring the manual connection of backup power supplies.
- *Nominal*—not difficult to perform. There is little ambiguity. An easily managed number of variables or inputs are involved. The organization of information or execution of steps is relatively straightforward with little potential for confusion. Also, nominal should be chosen when this PSF is judged as not being a performance driver.
- *Obvious Diagnosis*—Diagnosis becomes greatly simplified. There are times when a problem becomes so obvious that it would be difficult for an operator to misdiagnose. The most common and usual reason for this is that validating and/or convergent information becomes available to the operator. Such information can include automatic actuation indicators or additional sensory

information, such as smells, sounds, or vibrations. When such a compelling cue is received, the complexity of the diagnosis for the operator is reduced. There are three characteristics needed to qualify a diagnosis as obvious. First, the situation needs to be relatively simple, a single event only. Second, the indications need to be clear and unambiguous. Third, it needs to be something the operators have experienced before (at least in training). An example that might fit this profile is an uncomplicated turbine trip, where a single cause results in multiple but consistent indicators and alarms, and the operators have seen it in the training simulator. For more complicated types of analyses such as event assessments, an example of an "*Obvious Diagnosis*" potentially could be the cue to start an RHR pump upon loss of shutdown cooling, depending on the specific situation. Note that there is no *obvious action* PSF level assignment for the Action calculation. Easy to perform actions are encompassed in the nominal complexity rate.

A crew or operator's understanding of the situation can influence complexity. If the crew does not have an adequate understanding of the nature of the problem, solving it becomes more complex, as the plant parameters often do not respond as expected. Key to assigning a level for this PSF is determining how challenging the situation is to the operator/crew. To a well-trained and experienced operator/crew, a particular situation might be simple, whereas for those poorly trained or inexperienced it might be very complex. As a general rule, the analyst should avoid double-counting the effects of a PSF. If the Experience/Training PSF is assessed negatively, the analyst should avoid including the effects of experience/training in the Complexity PSF.

3.4. Experience/Training

This PSF refers to the experience and training of the operator(s) involved in the task. Included in this consideration are years of experience of the individual or crew, and whether or not the operator/crew has been trained on the type of accident, the amount of time passed since training, the frequency of training, and the systems involved in the task and scenario. Another consideration is whether or not the scenario is novel or unique (i.e., whether or not the crew or individual has been involved in a similar scenario, in either a training or an operational setting). Specific examples where training might be deficient are guidance for bypassing engineered safety functions, guidance for monitoring reactor conditions during reactivity changes, and guidance for monitoring plant operation during apparently normal, stable conditions for the purpose of promoting the early detection of abnormalities.

The levels used for the Experience/Training PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Low*—less than 6 months of relevant experience and/or training. This level of experience/training does not provide the level of knowledge and deep understanding required to adequately perform the required tasks, does not provide adequate practice in those tasks, or does not expose individuals to various abnormal conditions.
- *Nominal*—more than 6 months of relevant experience and/ or training. This level of experience/ training provides an adequate amount of formal schooling and instruction to ensure that individuals are proficient in day-to-day operations and have been exposed to abnormal conditions. Also, this level should be assigned if the analyst judges Experience/Training to not be a performance driver.
- *High*—extensive experience; a demonstrated master. This level of experience/training provides operators with extensive knowledge and practice in a wide range of potential scenarios. Good training makes operators well prepared for possible situations.

If Training/Experience has been judged to be a performance driver, then this PSF might also include the quality of the training provided. If the simulator training does not match plant response, training might be judged as low. If the training does not cover the given situation, training might be judged as low, as would be the case if training were incomplete or incorrect. If the training for a particular situation is infrequently conducted, to the extent that important skills and concepts are not regularly rehearsed and refreshed, training might be considered low. Note that the threshold of 6 months of experience and/or training for the Low level should not be viewed as a firm rule; an activity that is well trained over five months may find the operator more qualified than one which is infrequently trained over multiple years.

Extensive experience and training does reduce the likelihood of error, but people can and have made errors despite being highly trained. Also, note that training and experience are considered here in the aggregate. Consequently, low experience might be offset by good training (and vice versa).

3.5. Procedures

This PSF refers to the existence and use of formal operating procedures for the tasks under consideration. Use of procedures and the assignment of a PSF level for Procedures can apply to either Diagnosis or Action (or both). Past problems seen in event investigations involving procedures include situations where procedures give wrong or inadequate information regarding a particular control sequence. Another problem that has been cited is ambiguity in procedure steps. PSF levels differ somewhat, depending on whether the activity is a Diagnosis activity or an Action. In situations where multiple transitions between procedures are required to support a task or group of tasks, SPAR-H suggests that the analyst adjust the PSF for complexity accordingly. If the procedures themselves are problematic, then the analyst should assess the procedures and determine whether they should be assigned an "Incomplete" or "Available, but poor" rating. However, as with all PSFs in SPAR-H, a prerequisite to evaluating this PSF quantitatively is the qualitative determination of whether or not Procedures are in fact a performance driver for the subject HFE.

The levels used for the Procedures PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Not Available*—the procedure needed for a particular task or tasks in the event is not available. However, this level should be used only if the analyst judges that the lack of procedures materially affects the error probability. If the analyst judges the Procedures PSF not to be a performance driver, then the Nominal level should be selected even though procedures might not be available.
- *Incomplete*—information is needed that is not contained in the procedure or procedure sections; sections or task instructions (or other needed information) are absent.
- *Available but Poor*—a procedure is available but it is difficult to use because of factors such as formatting problems, ambiguity, or such a lack in consistency that it impedes performance. This also includes procedures that are poorly designed, such as an important step being buried too deep within the procedure for operators to reach it in a timely manner.
- *Nominal*—procedures are available and enhance performance, or judged as not a performance driver.
- *Diagnostic/Symptom Oriented*—diagnostic procedures assist the operator/crew in correctly diagnosing the event. Symptom-oriented procedures (sometimes called function-oriented procedures) provide the means to maintain critical safety functions. These procedures allow operators to maintain the plant in a safe condition, without the need to diagnose exactly what the event is, and what needs to be done to mitigate the event. There will be no catastrophic result (i.e., fuel damage) if critical safety functions are maintained. Therefore, if either diagnostic procedures (which assist in determining probable cause) or symptom-oriented procedures (which maintain critical safety functions) are used, there is less probability that human error will lead to a negative consequence. This being said, if the symptom-based procedure is found to be inaccurate or awkwardly constructed, then the Procedures PSF should be negatively rated.

This PSF assesses the quality of procedures and other reference documents or information available to operators. If there is no procedure to cover the situation, then procedures are not available. The distinction between the levels "*Incomplete*" and "*Available but poor*" can be difficult to make, but generally, if a procedure is missing important information, it is "*Incomplete*." If the procedure contains incorrect or inaccurate information, if it allows for or directs improper actions, or if it is poorly organized, difficult to use or understand, then it is "*Available but poor*."

Contemporary control room operating procedures are written to be diagnostic or symptom oriented. There may be the temptation to credit this level automatically for the Procedures PSF. This has the effect of lowering the HEP by a factor of 10. The assignment of "*Diagnostic/symptom oriented*" for the Procedures PSF should only be undertaken when there is clear evidence that the procedures will quickly help the operators diagnose a situation that would otherwise be difficult or would take considerable additional effort to diagnose without particular procedural guidance. This is the exception, not the rule.

3.6. Ergonomics/HMI

Ergonomics refers to the equipment, displays and controls, layout, quality, and quantity of information available from instrumentation, and the interaction of the operator/crew with the equipment to carry out tasks. Aspects of the human-machine interface (HMI) are included in this category. The adequacy or inadequacy of computer software is also included in this PSF. Examples of poor ergonomics might be found in the panel design layout, annunciator designs, and labeling. Plant instrumentation generally corresponds to the Diagnosis aspect of crew performance, while plant controls correspond to the Action aspect.

The levels used for the Ergonomics/HMI PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Missing/Misleading*—the required instrumentation fails to support Diagnosis or post Diagnosis behavior, or the instrumentation is inaccurate (i.e., misleading). Required information is not available from any source (e.g., instrumentation is historically so unreliable that operators ignore the instrument, even if it is registering correctly at the time). Note that this PSF level also includes failed and faulty instrumentation and indications.
- *Poor*—the design of the plant negatively impacts task performance (e.g., poor labeling, needed instrumentation cannot be seen from a work station where control inputs are made, or poor computer interfaces).
- *Nominal*—the design of the plant supports correct performance, but does not enhance performance or make tasks easier to carry out than typically expected (e.g., operators are provided useful labels; the computer interface is adequate and learnable, although not easy to use). Again, as with all PSFs, the nominal level should be assigned whenever the analyst judges the PSF as not a performance driver.
- *Good*—the design of the plant positively impacts task performance, providing needed information and the ability to carry out tasks in such a way that lessens the opportunities for error (e.g., easy to see, use, and understand computer interfaces; instrumentation is readable from workstation location, with measurements provided in the appropriate units of measure).

Included in Ergonomics and HMI is the quality and quantity of information available from displays and gauges, control sensitivity and panel layout, usability of tools and quality of materials, and control accessibility, among others. If instrumentation is inaccurate, incomplete, missing, or unavailable, then HMI is "*Missing/Misleading*." Issues such as poor panel displays or layouts, inadequate control sensitivity or accessibility are best assessed as "*Poor*." Note that although a typical control room console may not meet usability criteria of being intuitive or easy to use, the extensive training and experience of the crew allows them to interact with the system in an effective manner. They are able to get the information they need to monitor and diagnose plant states, and they are able to control all necessary parameters. Any deficiency in this basic functionality should be considered "*Poor*" or "*Missing/Misleading*."

See Whaley et al. (2011) for additional discussion of the Ergonomics/HMI PSF.

3.7. Fitness for Duty

Fitness for duty refers to whether or not the individual is physically and mentally suited to the task at hand. The levels used for the fitness for duty PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Unfit*—the individual is unable to carry out the required tasks, due to illness or other physical or mental incapacitation (e.g., having an incapacitating stroke).
- *Degraded Fitness*—the individual is able to carry out the tasks, although performance is negatively affected. Mental and physical performance can be affected if an individual is ill, such as having a fever. Individuals can also exhibit degraded performance if they are inappropriately overconfident in their abilities to perform. Other examples of degraded fitness include experiencing fatigue from long duty hours; taking cold medicine that leaves the individual drowsy and inattentive; or being distracted by personal bad news (such as news of a terminal illness diagnosis of a loved one).
- *Nominal*—the individual is able to carry out tasks; no known performance degradation is observed. Nominal should also be used when the analyst judges the PSF as not a performance driver.

Fitness for Duty encompasses much more than fatigue, such as impairment due to drugs (prescription, over-the-counter, or illegal) or alcohol, distraction due to personal or family issues, whether a person is physically or mentally capable of performing a task, or boredom. These issues are rarely documented in event reports, however; so, the most common Fitness for Duty issue cited is fatigue.

Time of day plays a role in Fitness for Duty. For example, it is not unusual for persons to become drowsy in the early afternoon, after lunch. For individuals accustomed to a night shift, cognitive functioning in the early hours of the morning is poorer than during the day. In circumstances such as this, a PSF assignment of "*Degraded Fitness*" might be appropriate. The type of task a person is working on also influences fitness for duty: it is well documented that people are bad at extended vigilance or monitoring tasks. Performance typically drops after about 30 minutes of continuous monitoring.

3.8. Work Processes

Work Processes refer to aspects of doing work, including inter-organizational, safety culture, work planning, communication, and management support and policies. How work is planned, communicated, and executed can affect individual and crew performance. If planning and communication are poor, then individuals might not fully understand the work requirements. Work Processes include consideration of coordination, command, and control. Work Processes also include any management, organizational, or supervisory factors that may affect performance. Examples seen in event investigations are problems due to information not being communicated during shift turnover, as well as communication with maintenance crews and auxiliary operators.

The shift supervisor also plays a major role in Work Processes. Instances where the shift supervisor gets too involved in the specifics of the event—in contrast to maintaining a position of leadership in the control room—would indicate a breakdown in Work Processes. Additionally, any evidence obtained during the review of an operating event indicating inter-group conflict or indecisiveness (e.g., between engineering and operations), or an uncoordinated approach to safety, is evaluated in SPAR-H as a Work Process problem. Schisms between operators and management are also considered Work Process problems.

Because there are so many potential areas of concern within the Work Process category that influence assignment of a PSF level, the analyst is directed to provide as much information as possible in the worksheet space provided, listing the reasons for assigning a particular Work Processes PSF level. Again, only in cases where Work Processes have been identified as a performance driver for the HFE in question should a non-nominal PSF level assignment be used.

The levels used for the Work Processes PSF in SPAR-H (in addition to *Insufficient Information*) are:

- *Poor*—performance is negatively affected by the work processes at the plant (e.g., shift turnover does not include adequate communication about ongoing maintenance activities; poor command and control by supervisor(s); performance expectations are not made clear).
- *Nominal*—performance is not significantly affected by work processes at the plant, or work processes do not appear to play an important role (e.g., crew performance is adequate; information is available, but not necessarily proactively communicated). The analyst should select nominal when the PSF is judged as not a performance driver.
- *Good*—work processes employed at the plant enhance performance and lead to a more successful outcome than would be the case if work processes were not well implemented and supportive (e.g., good communication; well-understood and supportive policies; cohesive crew).

Work Processes is a "catch-all" PSF, encompassing organizational and management issues, cultural issues, safety culture, communications, crew dynamics, work planning and scheduling, supervision, conduct of work, and problem identification and resolution. The assignment of "*Poor*" or "*Good*" should follow from clear indications that aspects of work processes degraded or enhanced performance. For example, simply having a crew that communicates well is not sufficient reason to credit "*Good*" for Work Processes. If, on the other hand, good communication clearly helped to quickly diagnose an event at the plant, it would be appropriate to credit Work Processes as "*Good*." Because so many factors are encompassed under Work Processes, it might be possible that a particular situation both features positive and negative aspects of the same PSF. In such cases, the most dominant factor should be considered as the main weighting factor. Precedence may be given to factors that degraded performance in such cases.

See Whaley et al. (2011) for additional discussion of the Work Processes PSF.

4. STEP 3: CALCULATE PSF-MODIFIED PSF

Once the PSFs levels have been assigned, then the final HEP is simply the product of the nominal HEP and the PSF multipliers. When Diagnosis and Action are combined into a single HFE, the two HEPs are calculated separately and then summed to produce the composite HEP. The analyst should note that HEPs are probabilities of the union of Diagnosis and Action and should be calculated accordingly. The SPAR-H documentation in Gertman et al. (NUREG/CR-6883; 2005) does not limit the probability of the union of Diagnosis and Action, meaning it is possible to have a value exceeding 1.0. However, if the two probabilities are small, then the simple arithmetic sum is acceptable. In the event that a combined Diagnosis and Action HEP approaches or exceeds 1.0, the following equation should be applied:

$$HEP(Diagnosis + Action) = HEP(Diagnosis) + HEP(Action) - [HEP(Diagnosis) \times HEP(Action)] \qquad (1)$$

If multiple PSFs have been judged to negatively impact an HEP, then there is the possibility that the final individual HEP might be greater than one. If this is the case, then an *adjusted* PSF is calculated and used in the formula provided in the worksheets:

$$HEP = \frac{NHEP \cdot PSF_{composite}}{NHEP \cdot (PSF_{composite} - 1) + 1} \qquad (2)$$

where $NHEP$ is the respective nominal HEP for Diagnosis and Action and $PSF_{composite}$ is the product of the PSF level multipliers. This formula will ensure that the individual Diagnosis and Action HEP values do not exceed a probability limit of 1.0.

5. STEP 4: ACCOUNT FOR DEPENDENCE

Guidance for dependence assessment in SPAR-H is discussed at length in a separate paper (Whaley & Kelly, these proceedings) and in Whaley et al. (2011).

6. STEP 5: MINIMUM CUT-OFF VALUE

In past applications of HRA in general, and SPAR-H in particular, questions have arisen concerning extremely small HEPs. Basically, the question is: how small can an HEP (or combination of HEPs in a sequence or cut set) become before it becomes unrealistic and unbelievable? As HEPs become smaller and smaller, the associated potential failure mechanisms become more and more incredible (but not impossible). At what point does the calculated HEP fall below the likelihood of very incredible (but possible) failure mechanisms, which are *not* being accounted for in the calculated failure probability?

This concept can be illustrated with a simple example. Based on the well-known Framingham Heart Study, the average rate of death from a heart attack in men ages 40–50 is about 10^{-6}/hr. Consequently, for calculated HEPs in the range of 10^{-2} to 10^{-4}, the contribution to the failure probability from incredible events like heart disease is insignificant and can be ignored. However, if a calculated HEP is in the range of 10^{-6} or lower, now the contribution to the total failure probability from death caused by heart disease is a significant contributor and needs to be accounted for in the HEP quantification. Or more specifically, how is a human error probability of 10^{-6} credible, when the probability of that operator becoming incapacitated (from a heart attack) is 10^{-6}?

When HEPs are down in the 10^{-6} range (literally, one in a million), failure mechanisms that would otherwise be judged to be insignificant contributors to the total failure probability and consequently could be ignored now become relatively important contributors that need to be included in the HEP estimate. There exist a virtually infinite number of potential failure mechanisms; as probabilities become smaller and smaller, more and more of these incredible failure scenarios become relevant to the failure modeling. It is for this reason that the lower bound on a single HEP in SPAR-H is suggested to be 10^{-5}. The analyst should understand that typical post-initiator HEPs are expected to be in the range of 0.1 to 10^{-4} (see section 5.3.3.8, page 5-17 of NUREG-1792; Kolaczkowski, et al., 2005).

The *Good Practices for HRA* document (Kolaczkowski, et al., 2005), does not address the issue of a lower bound on a single HEP, but recommends a joint HEP lower bound of 1E-5 for sequences or cut sets containing more than one HFE. After conferring with the authors of the *Good Practices* document, it is clear that this lower bound was motivated principally by concerns about dependence among HFEs in a cut set. Essentially, it was included to ensure that analysts consider dependence between HFEs in a cut set or sequence, but was not intended to constitute a hard and fast lower limit. It is permissible that a joint HEP be lower than 10^{-5} if there is a good basis for little or no dependence among the HFEs appearing in the sequence or cut set.

7. CONCLUSION

SPAR-H users have requested guidance on the proper use and application of the SPAR-H method, with specific questions regarding certain areas that need clarification: when to use Diagnosis and/or Action, guidance for PSF level assignments, guidance and clarification on dependence assessment, and the lower bound cut-off value. In response to these requests, staff at INL developed guidance to address these issues (Whaley, et al., 2011). This paper excerpts and summarizes that report, highlighting the five major steps for using the SPAR-H method and providing guidance on PSF level assignment. Guidance for dependence assessment using SPAR-H is provided in Whaley & Kelly (these proceedings). It is the intent of the authors that the guidance provided in these two papers should clarify a number of questions about application of the SPAR-H method and decrease inter-analyst variability.

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References

Boring, R. L., & Blackman, H. S. (2007). *The origins of the SPAR-H method's performance shaping factor multipliers*. Paper presented at the Joint 8th IEEE Conference on Human Factors and Power Plants and 13th Annual Workshop on Human Performance/Root Cause/Trending/Operating Experience/Self Assessment, Monterey, CA.

Electrical Power Research Institute (2010). Establishing Minimal Acceptable Values for Probabilities of Human Failure Events: Practical Guidance for Probabilistic Risk Assessment, Interim Report, EPRI-TR-1021081: Electric Power Research Institute.

Gertman, D. I., Blackman, H., Marble, J., Byers, J., & Smith, C. (2005). *The SPAR-H Human Reliability Analysis Method*. (NUREG/CR-6883). Washington, DC.

Kolaczkowski, A., Lois, E. L., Forester, J. A., & Cooper, S. (2005). *Good Practices for Implementing Human Reliability Analysis*. (NUREG-1792). Washington, DC.

Reason, J. (1990). *Human Error*. New York, NY US: Cambridge University Press.

Swain, A. D., & Guttman, H. E. (1983). *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications*. (NUREG/CR-1278). Washington, DC: U.S. Nuclear Regulatory Commission.

US Nuclear Regulatory Commission, & Electrical Power Research Institute, (2009). EPRI/NRC-RES Fire Human Reliability Analysis Guidelines, Draft Report, NUREG-1921. Washington, DC.

Whaley, A. M., & Kelly, D. L. (2012). *Guidance on Dependence Assessment in SPAR-H*. Paper presented at the Joint 11th Probabilistic Safety Assessment and Management (PSAM) Conference and the 12th European Safety and Reliability (ESREL) Conference, Helsinki, Finland.

Whaley, A. M., Kelly, D. L., Boring, R. L., & Galyean, W. J. (2011). SPAR-H Step-by-Step Guidance. INL/EXT-10-18533. Idaho Falls, ID: Idaho National Laboratory.