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Abstract—**The Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method has proved to be a reliable, easy-to-use method for human reliability analysis. Calculation of human error probability (HEP) rates is especially straightforward, starting with pre-defined nominal error rates for cognitive vs. action oriented tasks, and incorporating performance shaping factor (PSF) multipliers upon those nominal error rates. SPAR-H uses eight PSFs with multipliers typically corresponding to nominal, degraded, and severely degraded human performance for individual PSFs. Additionally, some PSFs feature multipliers to reflect enhanced performance. Although SPAR-H enjoys widespread use among industry and regulators, current source documents on SPAR-H such as NUREG/CR-6883 do not provide a clear account of the origin of these multipliers. The present paper redresses this shortcoming and documents the historic development of the SPAR-H PSF multipliers, from the initial use of nominal error rates, to the selection of the eight PSFs, to the mapping of multipliers to available data sources such as a Technique for Human Error Rate Prediction (THERP). Where error rates were not readily derived from THERP and other sources, expert judgment was used to extrapolate appropriate values. In documenting key background information on the multipliers, this paper provides a much needed cross-reference for human reliability practitioners and researchers of SPAR-H to validate analyses and research findings.**

I. INTRODUCTION

The Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method [1–3] was first released in 1995 as a simple-to-use approach for risk analysts to compute human error probabilities (HEPs). One way in which SPAR-H achieved simplicity was through the use of performance shaping factors (PSFs). A PSF is an aspect of the human's individual characteristics, environment, organization, or task that specifically decrements or improves human performance, thus respectively increasing or decreasing the likelihood of human error. Many early human reliability analysis (HRA) methods focused on the error likelihood of particular exemplar tasks or scenarios, whereby the risk analyst would map novel tasks or scenarios back to the pre-defined tasks or scenarios to extract an HEP. This scenario-based HRA approach (also called *holistic HRA*; see [4]) proved inflexible in application and was prone to mismatches. A different approach (also called *atomistic HRA*; see [4]) emerged in SPAR-H and other simplified HRA methods in which the risk analyst focused not on mapping whole tasks or scenarios but rather on mapping the applicable PSFs within those scenarios. The use of PSFs brought greater generalizability of HRA and greater inter-analyst reliability through simplified HEP estimation processes. However, early efforts to document PSF quantification, including SPAR-H, were incomplete. In order to provide better tractability of the SPAR-H method to human performance, this article retraces the origins of SPAR-H quantification.

II. HISTORY OF THE SPAR-H METHOD

SPAR-H was originally called the Accident Sequence Precursor (ASP) HRA [1], in recognition of its use within the ASP program of the US Nuclear Regulatory Commission (NRC). The method was developed as a closely related alternative to two popular approaches at the time. A Technique for Human Error Rate Prediction (THERP) [5] had been formally available as a method for over ten years, although aspects of THERP were available publicly in 1975 in the US NRC's *Reactor Safety Study* (WASH-1400) [6] and in even earlier work by the primary author [7]. THERP analyses required considerable training and topical mastery to complete [8]. Because of the difficulty in completing a THERP analysis under strict time and resource constraints, a simplified version of THERP was commissioned in 1987 and called the Accident Sequence Evaluation Program Human Reliability Analysis Procedure (ASEP) [9]. While based on THERP, ASEP estimates diverged from those in THERP. Moreover, the technique was often emphasized as a screening HRA method, meaning its use was primarily to provide rough estimates of error likelihood for risk determination. This approach contrasted with the nuanced results offered by THERP, offering in exchange a significant time savings and greater simplicity in terms of completing an analysis.

SPAR-H was born out of THERP and ASEP as a further simplification and generalization of these two approaches. The original ASP HRA method [1] was refined in 1999 and adopted the name of the Standardized Plant Analysis Risk (SPAR) probabilistic risk assessment (PRA) models developed in support of the US NRC [2]. This latter acronym, SPAR HRA, more clearly delineated the method from ASEP. The 2005 and most recent revision [3] adopted the acronym SPAR-H, whereby the H signified that this method was connected specifically with HRA vs. the broader PRA focus of the SPAR models. SPAR-H was contemporary to European HRA methods such as the Human Error Assessment and Reduction Technique (HEART) [10] and the Cognitive Reliability and

Error Analysis Method (CREAM) [11], which likewise went beyond the scenario-matching found in THERP, utilizing a series of PSFs for quantification.

SPAR-H eliminated the basic scenarios of THERP and focused on just two types of activities—*processing* and *response*. Processing referred to information processing or cognitive activities such as detection and decision making, while response referred to activities centered on behaviors and actions. This dichotomy was retained in subsequent revisions of SPAR-H but renamed *diagnosis* and *action*, respectively, to make the terms more universally understandable to a wide variety of analysts. Corresponding to these two types of activities are nominal HEPs. The context that acts upon these two types of scenarios is encompassed by a variety of PSFs, which serve as multipliers upon the nominal HEPs. This coupling of cognitive vs. behavioral activity types and PSFs affords a greater generalizability and flexibility to the analysis than can be found in scenario-based HRA. This approach is not without hazards, as acknowledged in the method documentation [3]—the data from which PSF multipliers are derived may not function in the multiplicative manner prescribed by the method, nor do the PSFs necessarily act orthogonally. The extent to which all quantitative PSF permutations and interactions in SPAR-H reflect actual human performance remains an important question for further empirical study.

III. Origins of the Nominal HEPs

As noted above, SPAR-H features nominal HEPs for processing/diagnosis and response/action activities. These values refer to the default or average expected error rate in the absence of PSF effects. The nominal HEPs have remained constant across all three versions of SPAR-H [1–3]:

- *Processing/Diagnosis:* Nominal HEP = 1E-2
- *Response/Action:* Nominal HEP = 1E-3

Note that these values differ from the suggested nominal HEP in THERP [5] and ASEP [9], which is 3E-2. This divergence is attributed to the disambiguation of cognitive and behavioral activities in SPAR-H. The nominal HEP for processing/diagnosis activities is based on the value found in THERP Table 20-1, Item 4, corresponding to the median HEP for a control room diagnosis task within 30 minutes. This follows the so-called 30-minute rule in control room activity—a general rule for how long operators should have available before they are required to take action [12]. The response/action HEP was derived from WASH-1400 [6] and numerous representative action tasks in THERP [5]. In WASH-1400, Appendix III, Table III 6-1, the erroneous activation of a switch, assuming no decision error, is estimated to be 1E-3. This corresponds to an archetypical nominal response/action in SPAR-H. THERP provides similar examples of response/action activities calibrated to an HEP of 1E-3:

- Incorrectly following a written procedure step (Table 20-7, Item 1)
- Incorrectly selecting an unannunciated display from similar-appearing displays (Table 20-9, Item 3)
- Incorrectly “check-reading” digital indicators (Table 20-11, Item 1) or analog meters (Table 20-11, Item 2)
- Inadvertently activating a control arranged in a well-delineated functional group (Table 20-12, Item 3)
- Incorrectly selecting or activating a locally operated valve that is clearly labeled and set apart from other valves (Table 20-13, Item 1)

IV. Origins of the PSFs and Multipliers

A. 1995 SPAR-H Version

The 1995 version of SPAR-H [1] included six PSFs, then known as *operational factors*. The selection of these six PSFs was based on the description of a cognitive model followed by the identification of factors known in the psychological literature to affect each step of that model. Using expert judgment by subject matter experts in nuclear power plant operations, this list was parsed into the six PSFs deemed to have the most relevance to and impact on human performance in terms of detection, perception, decision making, and actions in nuclear power plant operations. It is erroneous to conclude that this list of PSFs was intended to be exhaustive, although it was intended to be more complete than prior efforts in that it began from a basic cognitive model. The six PSFs were intended to represent the factors that could influence human performance, allowing a reasonable generalizability across situations and for which data could be extracted from THERP.

The six PSFs and accompanying HEPs are featured in Table 1. Each PSF features levels of effect, corresponding to different multipliers on the nominal HEP. Note that SPAR-H provides multipliers for each PSF (shown in parentheses in Table 1), not final or composite HEP values. However, the relationship between SPAR-H and THERP is best expressed in terms of the comparison of HEP values.

THERP does not clearly distinguish between processing/ diagnosis and response/action HEPs. For this reason, an HEP match is usually only possible between THERP HEP values and either processing/diagnosis or response/action HEPs in SPAR-H, but not both. Generalizing to the other case in SPAR-H is easy—in the 1995 version of SPAR-H, the PSF multipliers are identical for processing/diagnosis and response/action. Therefore, the only difference between processing/diagnosis and response/action HEPs is that processing/diagnosis HEPs are greater by a factor of 10.

Note that for the four initial PSFs—Complexity/Stress/ Workload, Experience/Training, Procedures, and Ergonomics—all PSF multiplier levels are directly linked to THERP values. The original SPAR-H development team utilized expert judgment to arrive at the best mapping of a THERP task or scenario item to the generalized SPAR-H PSF level. This mapping was subject to revision as experience was gained using SPAR-H in practice and as additional insights on the PSF level definitions were gained. The 1995 mapping of SPAR-H PSFs to THERP task types is as follows:

Complexity, Stress, and Workload. The multipliers for this PSF are taken from representative values in THERP Tables 20-

TABLE I. MAPPING OF ASP HRA (1995) TO THERP

ASP HRA/SPAR-H (1995)					THERP	
PSF	**PSF Category**	**PSF Level**	**Processing HEP[1]**	**Response HEP[1]**	**HEP for Processing[2]**	**HEP for Response[2]**
Complexity, Stress, and Workload	High Threat and Stress	Inadequate Time	1.0 (∞)	1.0 (∞)		1.0 (20-1, 1)
		Adequate Time	0.05 (5)	0.005 (5)		0.005 (20-23, 6)
		Expansive Time	0.02 (2)	0.002 (2)		0.002 (20-23, 4)
	Low Threat and Stress	Inadequate Time	1.0 (∞)	1.0 (∞)	1,0 (20-1, 1)	
		Adequate Time	0.01 (1)	0.001 (1)	0.01 (20-1, 4)	
		Expansive Time	0.01 (1)	0.001 (1)	0.001 (20-1, 5)	
Experience/ Training	Low Experience	Poor Training	0.1 (10)	0.01 (10)	10x (20-16, 5)[3]	
		Good Training	0.01 (1)	0.001 (1)	1x (20-16, 2)[3]	
	High Experience	Poor Training	0.05 (5)	0.005 (5)	5x (20-16, 5)[3]	
		Good Training	0.005 (0.5)	0.0005 (0.5)	0.5x (20-16)[4]	
Procedures	Procedures Absent	N/A	0.1 (10)	0.01 (10)	2x (20-22, 2)[5]	
	Procedures Present	Poor Procedures	0.05 (5)	0.005 (5)	0.05 (20-7, 5)	0.005 (20-6, 9)
		Good Procedures	0.01 (1)	0.001 (1)		0.001 (20-7, 1)
Ergonomics	Old Plant	Poor Ergonomics	0.05 (5)	0.005 (5)		0.005 (20-12, 12)
		Good Ergonomics	0.01 (1)	0.001 (1)		0.001 (20-12, 3)
	Retrofit Plant	Poor Ergonomics	0.03 (3)	0.003 (3)		0.003 (20-12, 2)
		Good Ergonomics	0.007 (0.7)	0.0007 (0.7)		0.0005 (20-12, 5)
	New Plant	Poor Ergonomics	0.02 (2)	0.002 (2)		0.003 (20-9, 4)
		Good Ergonomics	0.004 (0.4)	0.0004 (0.4)		0.0005 (20-9, 1)
Fitness for Duty	Unfit	N/A	0.25 (25)	0.025 (25)		
	Fit	N/A	0.01 (1)	0.001 (1)		
Crew Dynamics	Poor Crew Dynamics	N/A	0.1 (10)	0.01 (10)		
	Good Crew Dynamics	N/A	0.01 (1)	0.001 (1)		

[1]SPAR-H Multiplier in parentheses
[2]THERP table and item number (where applicable) provided in parentheses
[3]THERP provides multipliers, not HEPs, for these PSF levels
[4]Skilled workers decrease the HEP by a factor of two compared to novice workers.
[5]THERP specifies that performance is two times worse in the absence of procedures.

1 and 20-23. Table 20-1 represents a diagnosis within different time intervals by control room personnel for abnormal events annunciated closely in time. Table 20-23 represents a related occurrence—the time to take an action for multiple simultaneous annunciators. Thus, response/ action values are primarily taken from Table 20-23, while processing/diagnosis values are from Table 20-1. Note that the value for "Inadequate Time" for both processing/ diagnosis and response/action is taken from THERP Table 20-1, Item 1, which sets the HEP equal to 1.0 when there is inadequate time. Adequate time for "Low Threat and Stress" is assumed to be equivalent to having 30 minutes to complete the task (see discussion above on Origins of the Nominal HEPs). Having more time than 30 minutes corresponds to "Expansive Time" but is not credited with a different multiplier in SPAR-H, resulting in slightly more

conservative values than THERP. For the "High Threat and Stress" case, the 30-minute rule is applied again. It is assumed a crew will have sufficient time to address up to four annunciators in those 30-minutes (THERP Table 20-23, Item 4), corresponding to "Expansive Time" in SPAR-H. The crew will generally find they have "Adequate Time" to handle up to six such annunciators (THERP Table 20-23, Item 6). With increased annunciators beyond this point, the crew may find itself with "Inadequate Time" to respond to the annunciators.

Experience and Training. Experience and training is handled in THERP as a function of stress (Table 20-16), with separate levels of stress for skilled and novice operators. The difference between the effect of stress for skilled and novice people varies for action tasks between a factor of one for very low stress to a factor of five (skilled) and ten (novice) for moderately high or extremely high stress. These differences serve as the basis for the SPAR-H Experience and Training PSF levels.

Procedures. HEPs for Procedures involving action tasks in SPAR-H mirror the HEPs found in THERP across Tables 20-6, 20-7, and 20-22. Although THERP Chapter 15 [5] identifies the nominal HEP for written procedures to be 0.003, a careful analysis suggests that this value assumes a long procedure. Because procedures often do not fit THERP's criterion for a long procedure (with more than 10 steps), SPAR-H adopts as its nominal value the THERP HEP for short procedures, which is 0.001. As more deficiencies are identified with procedures or procedure use, the HEP value increments. SPAR-H adopts the step increases in HEP values found in THERP Table 20-7 although has slightly different definitions for each grade. The absence of procedures is handled in THERP Table 20-22, Items 1 and 2, which contrast performance during checking activities when procedures are available and when they are not. The lack of written materials, specifically procedures, suggests a twofold decrease in performance.

Ergonomics. The various levels of the Ergonomics PSF for response/action tasks in SPAR-H are a composite of effects documented in Chapter 14 of THERP [5]. The SPAR-H PSF is focused on crew interaction with instruments and controls but also includes perceptual aspects of displays covered in Chapter 11 of THERP, and manual control operations found in Chapter 13. Ergonomics PSF level multipliers for old and retrofit plants primarily follow those values found in THERP Table 20-12 for errors of commission in operating manual controls, a response/action activity in SPAR-H. Ergonomics PSF level multipliers for new plants are derived from values found in THERP Table 20-9 for erroneously selecting unannunciated displays, although the THERP values are slightly more conservative than those found in SPAR-H.

Fitness for Duty and *Crew Dynamics.* The two remaining PSFs—Fitness for Duty and Crew Dynamics—were not readily discernable from THERP as a primary data source. For Fitness for Duty, little empirical evidence was available to suggest distinct levels of degraded fitness. The effects of Fitness for Duty were, of course, well known across industries and had served as the most significant contributor to well-known accidents. As such, the SPAR-H method developers adopted a conservative screening value. In cases where Fitness for Duty should come into question, a multiplier of 25 was applied, resulting in a minimal overall HEP equal to 0.25 for processing/diagnosis tasks and 0.025 for response/action tasks.

The Crew Dynamics PSF encompassed communications and team interaction in command and control situations, which had been explored in human factors research studies but had not been linked directly back to levels of human reliability. As such, the SPAR-H method developers likened poor Crew Dynamics to situations in which there is poor training or a lack of procedures. Absent good communications especially between the shift supervisor and the reactor operator, the effect on performance is similar to what would be expected of a crew that was inadequately trained or did not have procedures to follow. Like the "Poor Training" PSF level for crews with Low Experience and like the "Procedures Absent" PSF level, "Poor Crew Dynamics" was given a multiplier equal to 10.

B. 1999 and 2005 SPAR-H Revisions

As noted earlier, the 1999 revision of SPAR-H [2] saw adoption of the name SPAR HRA method and a terminological shift from *processing* to *diagnosis* and from *response* to *action*. These changes were carried forward to the 2005 revision, by which time the method was called SPAR-H [3]. In terms of PSFs and PSF multipliers, the 1999 and 2005 revisions of SPAR-H [2–3] are almost identical. Both feature eight PSFs. The original single PSF entitled Complexity/Stress/Workload was deconstructed into three separate PSFs—Available Time, Stress and Stressors, and Complexity. New PSF levels and multipliers were split from the single set of PSF levels and multipliers, and, where required, the original mappings to THERP were revised.

Beginning with the 1999 SPAR-H revision, a number of new PSF levels were added that accounted for the possible positive influence of PSFs on human performance [13]. These multipliers were assigned values less than 1.0, effectively decreasing the HEP below the nominal HEP level when incorporated in the quantification. At the time THERP was developed, positive influences on human performance were not captured, and THERP provides no ready formula for crediting such influences. Therefore, it was necessary to extrapolate these positive influences to arrive at a new set of multipliers. Such values were inferred using expert judgment and do not have a direct link back to THERP or to empirical data. To avoid over-crediting such positive influences, the multipliers are conservative and have a negligible effect in decrementing the HEP.

The 2005 revision of SPAR-H [3] added two notable refinements to the 1999 revision. A new level was added to the Procedures PSF: "Incomplete" was inserted between "Not Available" and "Available but Poor," thus infilling a sizeable gap in accounting for procedural quality. The 2005 revision also added a second set of worksheets. To account for possible differences between At Power conditions and Low Power and Shutdown conditions, separate SPAR-H worksheets were created for each condition. While extensive documentation on the differences between At Power and Low Power and Shutdown is provided with the 2005 revision, currently, the only difference between these worksheets is in their definition of the Available Time PSF level entitled "Expansive Time." Because Low Power and Shutdown activities may benefit from the absence of the type of time pressure found during At Power operations, this multiplier is offered as a range between 0.1 and 0.01 for Processing/Diagnosis activities. The lower value is used in cases where little time pressure exists, for example, due to a planned extended maintenance outage.

A comparison of the PSF multipliers in the 1995 and 2005 versions of SPAR-H is found in Table 2. The current multipliers and their relationship to THERP are detailed in Table 3. Notable recalibrations of the multipliers are highlighted below.

Available Time. This new SPAR-H PSF aligns with THERP Table 20-1, which covers diagnosis of the first event in an abnormal event for different time durations. "Inadequate Time" in SPAR-H corresponds to "diagnosis within the first minute after the initiation of the abnormal event" in THERP (Item 1). "Barely Adequate Time" in SPAR-H corresponds to diagnosis within 20 minutes (Item 3). "Nominal Time" in SPAR-H corresponds to a diagnosis time within 30 minutes in THERP (Item 4). "Extra Time" in SPAR-H corresponds to a diagnosis time within one hour in THERP (Item 5). Finally, "Expansive Time" in SPAR-H corresponds to a diagnosis within one day in THERP (Item 6).

Stress and Stressors. Note that SPAR-H groups internal and external (e.g., environmental) stress into a single PSF, which maps to THERP's stress PSF (Table 20-16). This is consistent with THERP's treatment of environmental stressors (i.e., temperature, humidity, air quality, noise and vibration, illumination, and degree of general cleanliness) and physiological stressors (e.g., radiation exposure) under its Stress PSF. The THERP stress multipliers specifically for skilled personnel are used directly in SPAR-H. "Extreme Stress" in SPAR-H corresponds to Extremely High (Threat Stress) for step-by-step tasks in THERP (Item 6). "High Stress" in SPAR-H corresponds to Moderately High (Heavy Task Load) stress for step-by-step tasks in THERP (Item 4). "Nominal Stress" in SPAR-H is equivalent to Optimum stress for step-by-step tasks (Item 3) or dynamic tasks (Item 3) in THERP. Note that THERP considers the effects of inadequate stress (primarily due to inadequate arousal), which are not addressed in SPAR-H. THERP sets the HEP for extremely high stress during diagnosis at 0.25. SPAR-H retains the multipliers even in extreme stress, resulting in an HEP equal to 0.05, making THERP more conservative for extreme stress diagnosis tasks. However, it is noted in Chapter 17 of THERP [5] that there is large variability associated with extreme stress conditions. Further, THERP notes a paucity of data on performance during extreme stress conditions owing to the difficulty and ethical considerations in conducting such research. In light of the uncertainties associated with performance under extreme stress, SPAR-H balances crediting the operator and acknowledging risk.

Complexity. THERP does not directly treat complexity, which is newly treated as a PSF in SPAR-H. THERP does, however, cover a number of tasks involving complexity. The best direct match to complexity in THERP occurs in the operator response to simultaneous alarms (Table 20-23), which is included as part of the extended definition of complexity in the SPAR-H NUREG [3]. Correct response to a single alarm is given an HEP equal to 0.001 in THERP (Table 20-23, Item 1), while correct response to three alarms is deemed to have an HEP equal to 0.001 (Table 20-23, Item 3). This latter point is calibrated as the nominal HEP for action tasks in SPAR-H. For significantly fewer alarms, there is an enhancing effect of one order of magnitude, which is credited in SPAR-H for tasks with obvious diagnosis. The deleterious effects of complexity captured by SPAR-H are anchored to two additional points along THERP Table 20-23. Moderately complex tasks in SPAR-H are anchored equivalent to tasks involving four simultaneous alarms (Table 20-23, Item 4), producing an HEP equal to 0.002 for action tasks. Highly complex tasks are curve-fitted to the equivalent of six alarms (Table 20-23, Item 6), with an HEP equal to 0.005.

Procedures. THERP does not explicitly provide values for symptom-oriented procedures. In SPAR-H, the diagnosis PSF for procedures credits performance enhancement for procedures that are optimized by being symptom oriented. The positive influence is extrapolated on the distribution plot from the negative influence values.

Ergonomics and Human-Machine Interface (HMI). The nominal effect of Ergonomics and HMI corresponds to the "clearly and unambiguously labeled" HEP equal to 0.001 in Table 20-13, Item 1. While THERP offers five grades of degradation for the interface, SPAR-H adopts the value from Table 20-13, Item 5 ("unclearly or ambiguously labeled") with an HEP equal to 0.01 for the poor level of the PSF. SPAR-H includes a final PSF level corresponding to missing or misleading aspects of the interface, which is not found in THERP. To consider the magnitude of such an effect, SPAR-H adopts the worst effect HEP found in THERP for interface issues, found in Table 20-12, Item 6, with an HEP equal to 0.05. This condition corresponds to interfaces in which the design "...violates a strong population stereotype and operating conditions are normal" [5] for an error of commission in operating manual controls. Note that there exists a related HEP that is an order of magnitude stronger (Table 20-12, Item 7), but this HEP incorporates a significant consideration of stress, which is handled by a separate PSF in SPAR-H.

Fitness for Duty and *Work Processes.* The PSFs for Fitness for Duty and Crew Dynamics were significantly refined in the 1999 revision of SPAR-H. The authors referred particularly to HEART [10] for data, an HRA

TABLE II. COMPARISON OF 2005 SPAR-H AND 1995 ASP HRA PSF MULTIPLIERS

2005 SPAR-H		1995 ASP HRA			PSF Multiplier (SPAR-H | ASP HRA)	
PSF	**PSF Level**	**PSF**	**PSF Category**	**PSF Level**	**Processing/ Diagnosis**	**Response/ Action**
Available Time	Inadequate time	Complexity, Stress, Workload	Low Threat and Stress	Inadequate Time	∞ | ∞ (See Note 1)	∞ | ∞ (See Note 1)
	Barely adequate time				10 | ∅ (See Note 2)	10 | ∅ (See Note 2)
	Nominal time	Complexity, Stress, Workload	Low Threat and Stress	Adequate Time	1 | 1	1 | 1
	Extra time				0.1 | ∅ (See Note 2)	0.1 | ∅ (See Note 2)
	Expansive time	Complexity, Stress, Workload	Low Threat and Stress	Expansive Time	0.01 | 1 (See Note 3)	0.01 | 1
Stress/ Stressors	Extreme	Complexity, Stress, Workload	High Threat and Stress	Adequate Time	5 | 5	5 | 5
	High	Complexity, Stress, Workload	High Threat and Stress	Expansive Time	2 | 2	2 | 2
	Nominal	Complexity, Stress, Workload	Low Threat and Stress	Adequate Time	1 | 1	1 | 1
Complexity	Highly complex	Complexity, Stress, Workload	High Threat and Stress	Adequate Time	5 | 5	5 | 5
	Moderately complex	Complexity, Stress, Workload	High Threat and Stress	Expansive Time	2 | 2	2 | 2
	Nominal	Complexity, Stress, Workload	Low Threat and Stress	Adequate Time	1 | 1	1 | 1
	Obvious diagnosis				0.1 | ∅ (See Note 2)	
Experience/ Training	Low	Experience/ Training	Low Experience	Poor Training	10 | 10	3 | 10
	Nominal	Experience/ Training	Low Experience	Good Training	1 | 1	1 | 1
	High	Experience/ Training	High Experience	Good Training	0.5 | 0.5	0.5 | 0.5
Procedures	Not available	Procedures	Procedures Absent	N/A	50 | 10	50 | 10
	Incomplete				20 | ∅ (See Note 2)	20 | ∅ (See Note 2)
	Available, but poor	Procedures	Procedures Present	Poor Procedures	5 | 5	5 | 5
	Nominal	Procedures	Procedures Present	Good Procedures	1 | 1	1 | 1
	Diagnostic/symptom oriented				0.5 | ∅ (See Note 2)	
Ergonomics/ HMI	Missing/Misleading				50 | ∅ (See Note 2)	50 | ∅ (See Note 2)
	Poor	Ergonomics	Old Plant	Poor Ergonomics	10 | 5	10 | 5
	Nominal	Ergonomics	Old Plant	Good Ergonomics	1 | 1	1 | 1
	Good	Ergonomics	New Plant	Good Ergonomics	0.5 | 0.4	0.5 | 0.4
Fitness for Duty	Unfit	Fitness for Duty	Unfit	N/A	∞ | 25	∞ | 25
	Degraded Fitness				5 | ∅ (See Note 2)	5 | ∅ (See Note 2)
	Nominal	Fitness for Duty	Fit	N/A	1 | 1	1 | 1
Work Processes	Poor	Crew Dynamics	Poor Crew Dynamics	N/A	2 | 10	5 | 10
	Nominal	Crew Dynamics	Good Crew Dynamics	N/A	1 | 1	1 | 1
	Good				0.8 | ∅ (See Note 2)	0.5 | ∅ (See Note 2)

Notes

1. Multipliers are not used. Instead, the HEP is set to 1.0 for this PSF level.
2. This PSF level is not covered by the ASP HRA method.
3. The 2005 version of SPAR-H makes a distinction between At Power and Low Power or Shutdown in terms of the PSF multipliers. In practice, the only difference is that the multiplier for Expansive Time Diagnosis is given as a range of 0.1 to 0.01 for Low Power and Shutdown while only as a single multiplier of 0.01 for At Power.

TABLE III. MAPPING OF SPAR-H (2005) TO THERP PSF MULTIPLIERS

SPAR-H (NUREG/CR-6883)				THERP (NUREG/CR-1278)	
PSFs	**PSF Levels**	**HEP for Diagnosis[1]**	**HEP for Action[1]**	**HEP for Diagnosis[2]**	**HEP for Action[2]**
Available Time	Inadequate time	1.0 (no multiplier)	1.0 (no multiplier)	1 (20-1, 1)	
	Barely adequate time	0.1 (10)	0.01 (10)	0.1 (20-1, 3)	
	Nominal time	0.01 (1)	0.001 (1)	0.01 (20-1, 4)	
	Extra time	0.001 (0.1)	0.0001 (0.1)	0.001 (20-1, 5)	
	Expansive time	0.0001 (0.1-0.01)	0.00001 (0.01)	0.0001 (20-1, 6)	
Stress/ Stressors	Extreme	0.05 (5)	0.005 (5)	0.25	5x (20-16, 6)[3]
	High	0.02 (2)	0.002 (2)	2x (20-16, 4)[3]	2x (20-16, 4)[3]
	Nominal	0.01 (1)	0.001 (1)	1x (20-16, 2 or 3)[3]	1x (20-16, 2 or 3)[3]
Complexity	Highly complex	0.05 (5)	0.005 (5)		0.005 (20-23, 6)
	Moderately complex	0.02 (2)	0.002 (2)		0.002 (20-23, 4)
	Nominal	0.01 (1)	0.001 (1)		0.001 (20-23, 3)
	Obvious diagnosis	0.001 (0.1)	N/A		0.0001 (20-23, 1)
Experience/ Training	Low	0.1 (10)	0.003 (3)	2x (20-16, 7)[3]	2x (20-16, 4 or 5)[3]
	Nominal	0.01 (1)	0.001 (1)		
	High	0.05 (0.5)	0.0005 (0.5)		
Procedures	Not available	0.5 (50)	0.05 (50)		0.05 (20-7, 5)
	Incomplete	0.2 (20)	0.02 (20)		0.01 (20-7, 3)
	Available, but poor	0.05 (5)	0.005 (5)		0.003 (20-7, 2)
	Nominal	0.01 (1)	0.001 (1)		0.001 (20-7, 1)
	Diagnostic/symptom oriented	0.005 (0.5)	N/A		
Ergonomics / HMI	Missing/Misleading	0.5 (50)	0.05 (50)		0.05 (20-12, 6)
	Poor	0.1 (10)	0.01 (10)		0.01 (20-13, 5)
	Nominal	0.01 (1)	0.001 (1)		0.001 (20-13, 1)
	Good	0.005 (0.5)	0.0005 (0.5)		
Fitness for Duty	Unfit	1.0 (no multiplier)	1.0 (no multiplier)		
	Degraded Fitness	0.05 (5)	0.005 (5)		
	Nominal	0.01 (1)	0.001 (1)		
Work Processes	Poor	0.02 (2)	0.005 (5)		
	Nominal	0.01 (1)	0.001 (1)		
	Good	0.008 (0.8)	0.0005 (0.5)		

[1]SPAR-H Multiplier in parentheses
[2]THERP table and item number (where applicable) provided in parentheses
[3]THERP provides multipliers, not HEPs, for these PSF levels

method built on the CORE-Data [14] empirical database of HEP values. Fitness for Duty was delineated to two degraded levels beyond nominal performance. An "Unfit" level featured a multiplier set to infinity, or, more precisely, an automatic tagging of the HEP equal to 1.0. This keeps the conservative screening value adopted in the 1995 version of SPAR-H but makes the PSF treatment consistent with the treatment of the "Inadequate Time" level of the Available Time PSF. A new level was added for "Degraded Fitness" and given a multiplier of 5. This value proved slightly more conservative than the multiplier suggested in HEART [10].

The Crew Dynamics PSF was relabeled Work Processes and redefined to encompass a broader range of activities including plant culture and management involvement in activities. Two non-nominal levels were adopted for this PSF. The negative influence was captured in the "Poor" Work Processes level and aligned with HEART values for Error Producing Condition (EPC) 21. The positive influence was captured in the "Good" Work Processes level and aligned with CREAM [11] values for the Common Performance Condition (CPC) called Adequacy of Organization.

Note that in two cases the processing/diagnosis and response/action multipliers differ for the same level in the revised SPAR-H. "Low" Experience/Training has a multiplier of 10 for processing/diagnosis and 3 for response/ action. For "poor" Work Processes, processing/diagnosis features a multiplier equal to 2, while response/action has a multiplier equal to 5 at the same level. These values, like the positive influences that were not covered in the 1995 version of SPAR-H nor in THERP, represent refinements made through expert judgment based on the need to attenuate overly conservative values and accentuate effects that were undercounted previously. This process parallels the basis for all multiplier revisions in SPAR-H [13]. Where available, a mapping to THERP or other available HRA methods was performed. In a few cases as noted, however, it was necessary to extrapolate or estimate appropriate multiplier values.

V. DISCUSSION

HRA methods have proposed up to fifty PSFs [15]. SPAR-H attempts to provide reasonable coverage of the spectrum of human performance influences in nuclear power plant operations within the framework of the minimum reasonable number of PSFs. The decision to use first six PSFs and later eight PSFs was based on a review of then-available HRA methods in the early phase of SPAR-H development as well as ongoing feedback received by the SPAR-H Team from risk analysts at the US NRC. The SPAR-H quantification values used for the PSFs were based on available data within HRA, especially data provided in the THERP method [5].

The SPAR-H method provides a potent extension of THERP that allows the analyst flexibility and generalizability beyond narrowly defined tasks and scenarios. This approach does not guarantee valid HEP estimates. It does nonetheless provide a useful tool for categorizing and quantifying human contributions to risk and for facilitating risk-informed decision making.

This paper provides a mapping of the PSF multipliers in SPAR-H to primary data, especially those HEPs originating in THERP. This mapping improves the tractability of SPAR-H estimates. However, it must be remembered that the primary data sources for HRA are not infallible or infinitely generalizable. A quality HRA should not rely blindly on the estimates provided by a particular HRA method, be it SPAR-H or any other method. Rather, the HRA team should carefully consider NUREG-1792, *Good Practices for HRA* [16], which advises analysts to "evaluate the reasonableness of HEPs obtained" through "plant history, comparisons with results of other analyses, and qualitative understanding of the actions and their contexts by experts" (Good Practice 8).

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