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Abstract—**The Human Event Repository and Analysis (HERA) system has been developed as a tool for classifying and recording human performance data extracted from primary data sources. This paper reviews the process of extracting data from simulator studies for use in HERA. Simulator studies pose unique data collection challenges, both in types and quality of data measures, but such studies are ideally suited to gather operator performance data, including the full spectrum of performance shaping factors used in a HERA analysis. This paper provides suggestions for obtaining relevant human performance data for a HERA analysis from a control room simulator study and for inputting those data in a format suitable for HERA.**

I. Introduction

The Human Event Repository and Analysis (HERA) system [1] was developed as a tool for classifying human performance data extracted from primary data sources such as event reports. The HERA system provides a comprehensive taxonomy for human performance, with a particular emphasis on those factors that shape human performance at nuclear power plants. HERA serves as a framework for cataloging human performance, providing a worksheet based classification scheme and a database for storing and trending findings across multiple data sources.

HERA records a variety of performance shaping factors (PSFs) based on good practices in human reliability analysis (HRA) [2]. As a representation of safe and unsafe human activities, HERA entries provide qualitative indications of the relationship between human performance and context. HERA also provides a potential quantitative basis for computing frequentist human error probabilities or for updating existing probabilities in a Bayesian statistical framework. HERA allows the computation of a denominator of total actions contained in the HERA database, such that the human error probability may be considered a function of the number of unsafe actions contained in HERA divided by the total number of actions. The more activities that are recorded and the more representative such activities are, including routine and successful human activities, the more complete the HERA representation is.

The requisite large data basis for frequentist estimation is, however, hindered by the lack of detailed human performance data in many event reports. Event report data are well suited to the timeline approach used by HERA but may fail to provide a complete and nuanced account of human performance during the event [3]. This lack of detail is largely due to the retrospective nature of event reporting. Event reports typically document those human performance considerations known to have a causal connection to specific outcomes in the event [4]. They do not typically document the full range of human activities, including positive human actions that may have indirectly contributed to a safe event outcome. To capture all activities in addition to reportable deficits in human performance, it may be necessary to assemble an event inspection team [5]. A careful and costly reconstruction of operator activities by an inspection team is not always feasible, nor is it always necessary, especially when the risk significance of an event is negligible.

One data source that can consistently provide a complete snapshot of human performance is control room simulator studies. Simulator studies present opportunities to compare actual crew performance to expected task performance or even procedural requirements and attempt to discern causes for any deviations. Control room studies such as those conducted at the HAlden huMan-Machine LABoratory (HAMMLAB) [6] provide insights into nuclear power plant control room crews when confronted with a variety of normal and off-normal scenarios. Unique to such studies is the ability not only to record all crew interactions and communications but also to:

- Manipulate the scenario and corresponding external PSFs (e.g., environmental factors, quality of the interface, number of simultaneous tasks, etc.);
- Precisely assess performance measures (such as time to complete tasks) that clearly map to the PSFs used in HERA; and
- Utilize additional measures such as crew self-

assessment of performance during the scenario.

HERA includes provision for the input of simulator studies. However, the manner in which findings from simulator studies may best be input into HERA is not necessarily self-evident. This paper provides a brief overview of the differences and similarities between event and simulator study data. This paper also provides suggestions for obtaining relevant human performance data for a HERA analysis from a simulator study and for organizing those data in a format suitable for input into HERA.

II. Differences between Simulator Studies and Event Reports

A. Initiating Events

A major difference between simulator studies and reportable events at power plants is that simulator studies need not necessarily encompass a negative plant state such as an initiating event—a perturbation to the steady state operation of the plant that potentially challenges plant control and safety systems. Nor are simulator studies necessarily expected to demonstrate crew performance deficits. It is possible to conduct a simulator study in which no initiating event and no discernible performance deficits occur. Such routine and safe situations occur every day at operating plants. But, because these operations never degrade below a minimum safety threshold, they are not reported. Consequently, there are few extensive records of the routine but safe human actions at plants. Simulator studies represent the opportunity to record human performance during normal operations. Such activities may prove important baselines against which operator performance in off-normal circumstances can be compared.

For those simulator studies that feature negative plant states, it must be noted that these states are often triggered by the investigator. For example, a simulated steam generator tube rupture (SGTR) may be artificially initiated by the investigator to gauge subsequent crew response. For artificially initiated events, the focus of the study is not on the root cause of the initiator but on the crew's post-initiator performance. Safe post-initiator crew performance is characterized by activities that address the unsafe initiator.

B. Simulator Data Types

Simulator studies pose unique challenges in terms of the types of data that are gathered. Simulator studies are generally ideally suited to gather crew response time [7]. However, a simulator study must be carefully designed in order to record the data required for a comprehensive HERA analysis. PSF data are not readily extracted from simulator data simply by virtue of the data coming from a controlled study. Rather, the study should be designed to account for the data suited to HERA, and appropriate measures such as independent and dependent variables must be incorporated into the study.

While it would be desirable to use data derived from a plant's training simulator log files, such data do not automatically lend themselves to a full spectrum of HERA analysis. In order to complete a HERA analysis, it is crucial to understand what factors were manipulated, what crew-related PSFs came into play, as well as the scenario outcome in terms of success or failure. These factors are not automatically recorded in typical training simulator runs. Extraction of such factors can prove laborious and time-consuming when not incorporated into the original study design.

Braarud et al. [8] note measures that are used in HAMMLAB control room simulator studies. These measures provide an example of the types of data needed to capture the complete human performance inputs favored for HERA coding. Braarud et al.'s measures are listed below:

- Open-ended crew interview
- Operators' PSF self-ratings and comments
- Operator background questionnaire
- Expert observer's PSF ratings, comments and crew performance rating
- Itemized activity log for the crew
- Verbal protocol or commentary of crew activity by expert observer
- Time-stamped simulator logs including all crew interactions with system
- Audio and video of all crew members during the scenario

Any PSFs collected in a simulator study should, whenever possible, be aligned to those PSFs used in HERA. Other PSFs may, of course, be used, but these should, as feasible, be mapped to the HERA PSFs for completeness and maximum compatibility.

C. Simulator Study Timeline

During HERA coding, an event report is deconstructed into an event timeline that chronicles positive and potentially negative human, plant, and contextual subevents at the plant. In contrast, a simulator study does not necessarily produce a single timeline, as a scenario is typically tested using multiple crews that may experience different outcomes. To facilitate comparison between crews performing the same scenario, it is important to construct an a priori timeline based on the different phases of a planned scenario. Consider, for example, a study to detect and control an SGTR at a pressurized water reactor. Appropriate high-level tasks of these activities might include:

- Detect and identify SGTR
- Isolate steam generator (SG)
- Cool down reactor cooling system (RCS)
- Depressurize RCS
- Terminate safety injection
- Achieve pressure balance

These phases could be further parsed into subtasks. For example, to isolate the SG, the operators would need to isolate the faulted SG according to emergency operating procedures, set the steam dump atmosphere valve set point to the appropriate pressure level, and alert personnel and emergency organizations.

Given the low human error probability for most control room tasks, each crew will ideally perform these tasks successfully as prescribed by the operating procedures. Thus, the timeline for a simulator study may consist entirely of *successful human activities* (HSs in HERA parlance), which is less common in analyses of reportable events. Naturally, there is also the possibility that certain simulator crews will fail to complete all required activities successfully or within prescribed time constraints. Such actions may be recorded as *unsuccessful human activities* (XHEs in HERA). In addition to such Boolean success/failure states, a control room or process expert may subjectively rate each task on a scale, providing a degree of success or failure. In such cases, the expert should also provide specific comments to clarify the ratings, which may be used to help assign the PSFs for each task.

Given the same scenario and phases across multiple crews, how should HERA analysts construct the scenario timeline? There are special considerations for simulator study data in terms of the level of task decomposition and the input of data from multiple crews.

1) Subevent Granularity

The granularity of the subevent decomposition is a reflection of the data collection goals. Using the above SGTR example, the analyst may be interested in the detailed steps each crew takes to complete each task. In such a case, the timeline will feature each task along with subtasks, each treated as subevents in HERA. The analyst may cluster the subtasks together to indicate they belong to a single series of actions. By *clustering,* the analyst elects to list the subtasks as separate subevents in HERA but then group them together for coding efficiency. It is assumed that when subevents are clustered, they feature common characteristics and performance shaping factors that do not warrant separate detailed coding as subevents. The HERA system provides functionality to support such clustering.

Alternately, if the analyst is not interested in detailed task decomposition, he or she may elect high-level tasks corresponding to the main tasks but excluding the subtasks. These high level tasks correspond to the subevents in the timeline, without treating each subtask as a separate subevent. In other words, some subtasks may be purposefully omitted in order to provide a clearer timeline and avoid the need to cluster subevents. This approach may be adopted, for example, when performing a HERA analysis based on Human Failure Event (HFE) cutsets in probabilistic risk assessment (PRA).

Note that a priori clustering of subtasks as part of a single task or subevent is possible for simulator studies but not for event data. Clustering for simulator studies reflects the controlled nature of the study design. Event data must establish a clear performance pattern before being clustered. Because simulator studies typically represent carefully controlled scenarios, it is uniquely possible to cluster subtasks prior to data collection on the basis of shared scenario or situational characteristics.

2) Input of Data from Multiple Crews

Simulator data are usually the product of multiple crew runs over multiple scenarios, thus producing a wealth of data for possible inclusion in HERA. Consider the SGTR example, decomposed to the primary task level presented earlier. In a hypothetical study involving ten crews, all crews successfully detect and identify the SGTR, isolate the SG, cool down the RCS, and achieve pressure balance. However, one crew fails to depressurize the RCS in the prescribed time, while another crew initially fails to terminate the safety injection (but eventually recovers and achieves pressure balance, albeit at a significant delay compared to other crews).

This example reveals a particular nuance of efficiently coding simulator studies into HERA. It is possible to model the actions of each crew separately and generate ten separate timelines with corresponding Part B worksheets. This process would likely result in ten separate event entries, each with six subevents corresponding to the major tasks of interest in the SGTR. Without software assistance to duplicate event and subevent level information, coding would be particularly laborious, because manually entering nearly identical data records could prove unduly repetitive, while attempts to extract meaning of the separate crew entries would likely prove problematic without careful cross-referencing between crews and scenarios.

To address this issue, HERA provides specific data fields that facilitate the categorization of simulator data. In the HERA Overview Worksheet (Worksheet A), the analyst may indicate that the data are part of a simulator study. Four text fields accompany the designation of a simulator study:

- Experiment Information
- Scenario
- Variant
- Crew

The *Experiment Information* field is used to provide a short description of the overall simulator study under investigation (e.g., "SGTR Complexity Study"). Since each simulator run is treated as a separate event entry, it is the Experiment Information field that ties the different events together. Separate events that feature the same Experiment Information field are considered part of the same study. The *Scenario* field is used to delineate groups of experimental manipulations, as required. The overall study might, for example, feature two scenarios, corresponding to independent variables that are manipulated (e.g., "Basic SGTR" vs. "Complex SGTR"). Further variations of the scenarios would be featured in the *Variant* field (e.g., "Clear Indicators" vs. "Misleading Indicators"). Finally, the *Crew* field allows the analyst to record which crews correspond to each scenario and variant. Table 1 shows the concatenation of the levels of scenario and variant manipulations coupled with the crews tested in those scenarios.

TABLE I. EXAMPLE SIMULATOR STUDY SCENARIO, VARIANT, AND CREW ASSIGNMENTS

Experiment	SGTR Complexity Study		
Scenario	Basic SGTR	Complex SGTR	
Variant		Clear Indicators	Misleading Indicators
Crew	1 – 10	1 – 5	6 – 10

Note in the example that the scenario is a *within-subject design*, whereby all crews participated in both the "Basic SGTR" scenario and the "Complex SGTR" scenario. The two variants of the "Complex SGTR" scenario are a *between-subject design*, whereby different crews participated in different experimental conditions. According to the information in Table 1, the overall study would consist of three separate timelines, corresponding to the Scenario and Variant combinations. In other words, a separate set of HERA worksheets would be coded for each of the crews featured on the bottom line. The total number of events coded would be 20, corresponding to the ten crews in the "Basic SGTR" condition and the same ten crews in the "Complex SGTR" condition, five crews each for the "Clear Indicators" and "Misleading Indicators" scenario variants.

Rather than manually code data for each crew, the software version of HERA makes it possible to duplicate event data, including all subevents. It may be useful to code the most typical crew first as an event and then duplicate that event, customizing the details of the event and subevent analysis to reflect the particular crew's performance. In the worksheet version of HERA, the analyst would need to code crews separately.

Note that it is important not to attempt to aggregate data from multiple crews into a single event. In order for proposed forthcoming HERA software data extraction features to function properly, it is necessary for there to be a complete set of records for all crews that were tested in a simulator study. Aggregated data can lead to underestimation of performance frequency when the HERA software are used to trend across multiple events. Proposed HERA software data extraction features would also provide tools to allow easy comparisons and summaries within an experiment, thereby obviating the need for manual aggregation of the data across crews.

III. Simulator Study PSFs

As discussed earlier, it is crucial for the simulator study to be designed in such a way that it is possible to collect the PSF information required by HERA. In event reports, PSFs must be carefully weighed in the face of available reported data. Simulator studies afford the opportunity to collect all necessary data to assign the PSFs with a minimum of expert inference.

It is useful to review the three types of simulator and simulation PSFs discussed in Boring [9]. In an event or simulator study, PSFs may be considered *static conditions*, *dynamic progressions*, or *dynamic initiators* (see Table 2). These three PSF types are explained below.

TABLE II. Types of PSFs to consider in simulator studies

Static Condition	**Dynamic Progression**	**Dynamic Initiator**
PSFs remain constant across the events in a scenario.	*PSFs evolve across events in a scenario.*	*A sudden change in the scenario causes changes in the PSFs.*

A *static condition* denotes a scenario or event in which the PSFs remain constant. An example of such a PSF in HERA is "Fitness for Duty / Fatigue." Especially in the context of the relatively short duration of simulator study runs, there is typically little opportunity for fitness for duty or the fatigue of the operators to degrade during the course of the study. Physical injury or sudden emotional stress are also ruled out as possible effects on the operators' fitness for duty during the simulator run. Since this PSF is not expected to change during the simulator run, it is not necessary to monitor this PSF during the study. (The exception to this guidance would be studies that specifically manipulate fitness for duty in some manner.) It is helpful to take an initial measure of this PSF or to assign it a known value based on the investigator's expertise. This initial, static measure may then be used to pre-populate detailed PSF information across scenario subevents, thereby increasing the efficiency with which other information can be incorporated into HERA. Unless there are significant situational or contextual changes during a scenario (such as caused by a dynamic initiator), the following HERA PSFs may typically be considered static conditions: Experience & Training, Procedures & Reference Documents, Ergonomics & HMI, Fitness for Duty / Fatigue, Environment, and Team Dynamics / Characteristics. Communication may also prove to be a static condition for a well-seasoned crew that has developed significant cohesion and that does not include new members.

Note that each of these PSFs may, in fact, change dramatically throughout a scenario. An experienced and highly trained crew may encounter a novel situation for which they have minimal training and experience. Quality procedures may fail to cover an unusual or unexpected plant state. An overall effective HMI may suddenly give a misleading indicator. A fit operator may gradually become fatigued. Trusted systems in the environment such as lighting may fail. Otherwise stable team dynamics may prove forfeit in the face of particularly stressful and complex events. In a carefully controlled simulator study, such changes are most likely the result of the investigator's manipulation of the scenario to trigger changes in the PSFs in order to measure their effects on crew performance. See the discussion below on dynamic initiators.

A *dynamic progression* encompasses those PSFs that naturally change and evolve across the scenario. These PSFs should be assessed or monitored regularly throughout the scenario to allow a mapping between the tasks (subevents) and PSFs. "Complexity" is an example of a PSF that is expected to change throughout the course of the scenario. As the scenario evolves, the operators are constantly required to monitor plant indicators and take appropriate actions. Simultaneous tasks, ambiguity, simultaneous alarms, and other factors combine to vary the situational complexity throughout the operation of the plant. The following HERA PSFs may in many cases be considered dynamic progressions: Available Time, Stress & Stressors, Complexity, and Communication.

In some cases, it may be appropriate to treat static condition PSFs dynamically, especially in particularly dynamic scenarios. Note that static condition and dynamic progression are not mutually exclusive categories. The decision to treat a PSF as static or dynamic resides with the investigator or analyst and is a function of practical considerations in terms of the amount of recurring data collection that is required during the simulator study scenarios. The delineation provided here serves as general guidance that is applicable to many scenarios.

A *dynamic initiator* occurs when any PSF is altered by a sudden change in the simulator study scenario. Almost any PSF, whether normally treated as static or dynamic, may respond to a sudden change in the scenario. Consequently, following the introduction of an experimental manipulation, it is useful to monitor the status of PSFs. For example, the introduction of a plant trip and the crew's entry into emergency operating procedures is expected to alter the crew's actions and mental activities dramatically. The experimental manipulation has the potential to almost instantly change the PSF states that affect operator performance. For example, entry into an emergency operating procedure almost instantly changes the Available Time (e.g., time may suddenly become limited), Stress & Stressors (e.g., stress may elevate), Complexity (e.g., complexity may increase), Experience & Training (e.g., training may not have covered the situation at hand), and Procedures & Reference Documents (e.g., procedures may not fully address the situation). It may also alter Ergonomics & HMI (e.g., instrumentation may be affected by the situation), Work Processes (e.g., the novel situation may highlight new facets of work processes not covered by other situations), Communication (e.g., communication may degrade), and Team Dynamics / Characteristics (e.g., interactions may change in the face of an emergency situation). In some cases, the dynamic initiator cause may be ascribed to a single PSF. For example, a sudden loss of instrumentation or lighting would apply to the Ergonomics & HMI and Environment PSFs, respectively, and would have an almost immediate trickle-down effect to other PSFs.

Note that those PSFs that are deemed static conditions may be determined at one point in the study and left constant across subevents, unless there is a dynamic initiator. Also note that it is not possible to assign static conditions for most event reports. The static nature of PSFs results from the carefully controlled nature of simulator studies. In practice, of course, some PSFs found in event reports may prove static, but this can only be determined after careful assessment of the status of the PSF throughout the event. Static and dynamic PSFs are coded identically in the HERA worksheets. The difference between static and dynamic PSFs to the HERA analyst or the study investigator involves how often the PSFs are tracked and measured. Static PSFs are not typically tracked throughout the scenario; dynamic PSFs should be measured regularly and repeatedly.

IV. Tips for Encoding Simulator Data in HERA

The previous sections of this paper outlined key considerations for capturing control room simulator study data with HERA. This section provides a brief walkthrough of considerations pertaining to completing various parts of the HERA worksheets [10] for simulator data.

A. *Worksheet A, Section 1 (Plant and Event Overview)*

Primary Source Document Questions. When a published summary of the simulator study is available, this should be cited appropriately and linked in the software database. When no published summary is available, the cited source should denote the simulator name and date of study (e.g., "HAMMLAB Complexity Study, 2006, unpublished").

Plant Information Questions. To the extent appropriate, plant information should be captured including plant type, plant operating mode, and power level as modeled in the simulator. The "Other" field should be used to denote the degree to which the simulator is congruent with the crew's "native" plant control room. The less congruence there is, the more it is expected that the plant crew's performance will deviate from performance norms. Additional remarks regarding the fidelity of the simulator and the relationship between the simulated and native control room should be noted in Section 2 of the Worksheet.

Event Overview and Affected Systems Questions. Event information (particularly in terms of plant upset conditions) should be captured in these fields. This information only needs to be as complete as the underlying simulation. Where particular systems and functions are manipulated experimentally, these should be recorded. The time should be recorded in real time to reflect any time-of-day considerations that may be present during the simulator run. Proposed software tools in HERA would allow the analyst to switch between real time and elapsed time displays in the timeline.

Simulator Study Questions. As described previously, the essentials of the study design are recorded in terms of scenarios, variants, and crews. Each scenario or variant that requires a different crew will receive a separate Overview Worksheet (Worksheet A) and accompanying Detailed Activity Worksheets (Worksheet Part B) for the scenario tasks or subevents.

B. *Worksheet A, Section 2 (Event Summary / Abstract)*

Section 2 is designed to contain an event summary or abstract. From the perspective of recording the essential information of the simulator study, it is important that this section contains background information on the simulator type and configuration, including its similarity to the crew's native control room; a clear expression of the purposes, hypotheses, and goals of the study; details regarding all experimental manipulations, including explanations of the scenarios and variants; a description of the crews who participated in the study; and a summary of study findings.

C. *Worksheet A, Section 3 (Index of Subevents)*

It is useful to create a timeline or index of subevents a priori according to the design of the control room study. Typically scenario tasks are treated as subevents in the timeline. Subtasks may be clustered under a common task and treated as clustered subevents. As suggested earlier, simulator data may often contain only successful human activities (HSs). Unsuccessful crew activities (XHEs) may be determined by outright errors, failure to complete tasks according to specified criteria (e.g., within time constraints), or expert judgment of performance. Plant states and contextual information (i.e., EE, XEQ, EQA, PS, or CI in HERA) may also be included to the extent appropriate to capture the nuances of the scenario. Time should be recorded in real time, not as elapsed time since onset of the study.

D. Worksheet A, Section 4 (General Trends Across Subevents / Lessons Learned)

This section encompasses trends and lessons learned across the scenarios. Note that simulator study trends may not be causal in the same manner as for events. In many cases, the study investigator may manipulate factors to test human performance under adverse conditions. Thus, there is no implication of the crew or the plant conditions triggering adverse conditions. In many cases, the only cause of the adverse conditions is the investigator's experimental manipulation.

E. Worksheet A, Section 5 (Human Subevent Dependency Table)

This section features the Human Subevent Dependency Table. This section may not be relevant to all simulator studies, especially for those simulator studies that have only successful human activities (HSs) in their timeline. Dependency is only indicated for XHEs in HERA [3]. To the extent unsuccessful human activities are included in the simulator study timeline, dependency should be considered for simulator studies. If the dependency link between XHEs is caused by the experimental manipulation and not specifically by the links in crew performance, these should be clearly noted in the comments section. Simulator studies will typically involve the same crew performing actions close in time, which may be sufficient basis for assuming dependency. Analysts may also wish to consider the extent to which PSFs co-occur across subevents as additional criteria for establishing dependence.

F. Worksheet B, Section 1 (Personnel Involved in Subevent)

This section allows the HERA analyst to record which personnel were involved in the scenario. Typical simulator configurations focus on control room crews only and do not include, for instance, auxiliary operators, engineering staff, etc. It is therefore expected that most simulator studies will only feature personnel found under the "Operations" heading.

G. Worksheet B, Section 2 (Contributory Plant Conditions)

This section handles conditions at the plant. The HERA analyst should note which plant conditions are manipulated in the simulator scenario as well as which plant functions, systems, and components would be affected by the experimental manipulations.

H. Worksheet B, Sections 3 and 4 (Positive and Negative PSF Details)

Positive and negative contributory factors or PSF details call for expert knowledge about the interaction between the study scenarios, plant conditions, and the operators. As with PSFs, PSF details may be considered static or dynamic and may be treated appropriately. For static condition PSFs, it is typically sufficient for the study investigator and plant operations expert to evaluate the PSF details once across all conditions and for all crews. For dynamic progression and dynamic initiator PSFs, details should be recorded across scenarios for each crew.

It is useful to have an operations specialist who is trained on HERA definitions observe the live or recorded simulator runs for each crew and make expert ratings about the PSF details. To facilitate this process, it is possible to provide the observer an abridged HERA worksheet that only encompasses those PSF details deemed to be dynamic throughout the scenario. An abridged worksheet for dynamic PSFs should, of course, later be merged with the data for the static PSFs.

I. Worksheet B, Section 5 (PSFs)

In HERA analyses based on event reports, the PSF details serve as the basis for selecting a PSF level. This basis also applies to simulator study analyses, but the PSF details are not the only possible basis for the assignment of a particular PSF. The simulator study has additional detail available that may serve as evidence for the influence of a particular PSF. For example, subjective ratings on PSFs by the crew and by expert observers may indicate the influence of a PSF. Also, objective measures such as performance criteria, physiological measures, and simulator logs may indicate the influence of a particular PSF. These information sources augment the PSF details and should also be considered in the overall determination of PSF assignment levels. The overall use of such measures should be documented in the summary in Part A, Section 2. The specific metrics used to establish a particular PSF should be fully documented in the comments section of that PSF.

J. Worksheet B, Section 6 (Human Cognition)

Phases of human cognition such as detection, interpretation, planning, and action are recorded in this section. An analyst may wish to delineate overall tasks according to the constituent subtasks for the purposes of completing this section (e.g., a particular task may have subtasks separately related to detection vs. action, which may be treated as separate subevents). The analyst should exercise expert judgment in the classification of the cognitive steps involved in each scenario task.

K. Worksheet B, Section 7 (Error Type)

This section denotes the error type and should be assessed for each crew and subevent according to the guidance in Chapter 2. Note that across crews, for the same subevent, it may be possible that some crews succeeded (causing the subevent to be an HS), while some crews did not meet the success criteria (causing the subevent to be an XHE). This section should only be completed for those crews for which the subevent is classified as an XHE.

L. Worksheet B, Section 8 (Subevent Comments)

In this final section for general subevent comments, it is useful to paraphrase the overall performance findings of the task, particularly when crews differed from expected performance. Any manipulated PSFs or other causal factors should be noted here as well.

V. Coding for Non-Optimized Simulator Studies

The preceding discussion focused on coding HERA for simulator studies that are optimized to HERA's data collection format, particularly in terms of the collection of data for a full suite of PSF data. Of course, many simulator studies are not optimized for HERA, particularly with regard to the extensive PSF information ideally required to complete the HERA coding. It is nonetheless possible to use the data from such studies. When using such data, it is important to note in the overall event summary (Worksheet A, Section 2) what measures were available in the study that helped complete the HERA analysis. Equally importantly, the data that were not available (such as PSF data that were not recorded in the study) should be indicated. For unavailable data, fields denoting "not applicable" or "insufficient information" should be used, and comments should indicate that these areas were not available nor considered in the simulator study.

VI. Quality Assurance Process Guidelines for Simulator Studies

Quality assurance (QA) requirements for the analysis of simulator studies in HERA mirror requirements for the analysis of event reports [10]: Analysts should have proper training to understand and complete the HERA coding; analysts (potentially including the study investigator) should work together to complete the analysis and second-check the coding; it is important for the coding related to the simulator study to be externally reviewed. A key difference between simulator studies and event reports, however, is that a large part of QA in coding simulator studies takes place in the design and conduct of the study–before the study is actually coded into HERA. Important pre-coding considerations include:

- Design of the study to capture the data fields necessary for HERA. It is especially important to develop suitable measures that correspond to the HERA PSFs. These measures should ideally not rely solely on observer judgment or crew self-assessment, which may fail to capture the true range of human performance due to inherent human scaling biases [11]. Objective measures should be employed whenever practicable.
- Maximize the congruence between the crew's native control room and the control room simulator used in the study. A failure to utilize a close approximation can result in poor crew performance (due to a lack of experience and familiarity with the novel control room) and poor study generalizability. When differences between the simulator and the native control room plant are present, it is advisable to provide training to the crew on the novel control room prior to testing in the study. To avoid fatigue as a factor on performance, training and testing should not be conducted back-to-back. Although the surface features of the simulator interface may vary from those found in the native control room, issues of control room differences may be largely overcome by ensuring the functional similarity of the simulator and native control room interfaces [12].
- Develop clear criteria for successful crew performance on each task. By establishing guidelines such as what is considered an error and what amount of time is allowable to complete a task (in accord with plant procedural and regulatory guidelines), it is possible to eliminate the need for subjective classification of crew performance as successful or unsuccessful.
- Ensure complete and accurate data gathering during the simulator runs. The integrity of automated data collection tools and the utility of observer judgments and subjective ratings should be pre-tested and reviewed during the course of simulator runs. A performance measure that fails to gather data in the intended way can compromise the completeness of the HERA analysis.

During the extraction of simulator data into HERA, the HERA analyst should work closely with the study investigator to ensure the quality of the data input. The investigator should assume a prominent role alongside the analyst. The investigator is the main resource for constructing the event timeline and determining appropriate PSF data from the study. When the study investigator is not available, two or more analysts should work closely together in the construction of the timeline and the extraction of PSF data according to HERA's general QA guidance.

VII. Other Applications of HERA

The primary purpose of HERA is as a repository for data from event and simulator sources to support risk-informed decision making. This purpose does not preclude the use of HERA for other purposes. An example of a further application of HERA is in support of the ongoing empirical study of HRA methods [13]. This international study is designed to compare the findings of various HRA methods across the same scenario. This scenario is based on an SGTR study recently carried out in the HAMMLAB simulator. HERA was used as a common data framework for capturing the full range of PSF details found in various HRA methods, thus enabling ready comparison between the methods. As well, the predicted findings from the HRA methods, to the extent practicable, can be validated to those findings from the actual control room crews in the simulator.

The empirical study of HRA methods is illustrative of other applications of HERA. Because HERA provides a high-level taxonomy of positive and negative contributors to human performance, it can serve as a standardized data framework when it is necessary or desirable to conduct comparisons of different data sources. As demonstrated, HERA enables a comparison between the probabilistic framework of HRA methods and the empirical data of simulator studies. Other comparisons between different data types are quite possible within HERA. In addition, HERA provides the opportunity to capture diverse data in a standardized format, even when these data will not be utilized for comparative purposes.

VIII. Discussion

HERA has the capability to input data from both event reports and simulator studies. This paper has provided a first look at the process of capturing and inputting simulator study data for HERA. This process includes requirements for having as complete PSF details as possible, with a particular emphasis on the design of effective study measures. This process also includes formatting the data in such a way as to allow seamless incorporation into HERA. This two-pronged process, when carefully followed, affords the inclusion of a potentially significant number of successful crew activities from simulator studies, complementing data found in event reports. The synthesis of these two data sources uniquely provides a comprehensive snapshot of human performance, opening the door for more comprehensive analyses of human reliability in nuclear power plant control rooms.

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