EasyChair Preprint

№ 11332

Development of a Human Factors Hazard Model Using HEP / FTA / ETA

Dustin Birch and Thomas Bradley

November 18, 2023

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Dustin S. Birch[1] and Thomas H. Bradley[2]
Weber State University, Ogden, UT 84408
and
Colorado State University, Fort Collins, CO 80523

A new approach to Human Reliability Analysis (HRA), with applications in Systems Engineering (SE), is proposed. This new Human Factors Hazard Model (HFHM) utilizes the established and time-tested probabilistic analysis tools of Fault Tree Analysis (FTA) and Event Tree Analysis (ETA), and integrates them with a newly developed Human Error Probability (HEP) predictive tool. This improved approach to HRA is developed around human factors Performance Shaping Factors (PSF's) as well as the specific characteristics unique to each system architecture and its corresponding operational behavior. This new approach is intended to automate and simplify the approach to establishing the likelihood of a mishap due to the human-system interaction during a hazard event.

I. Nomenclature

Pf = *Intermediate Event Probability of Failure*
P_n = *Contributing Event Probability of Failure*
i = *Total Number of Contributing Events*
CPn = *Each Combination of n Elements for Contributing Event Probability*
T_{AR} = *Adjusted Reaction Time*
T_R = *Reaction Time*
M_A = *Human Actor Age Modifier*
M_F = *Actor Fatigue Modifier*
M_D = *Actor Distraction Modifier*
PF = *Probability of Failure in the Perception Pivotal Event*
PS = *Probability of Success in the Perception Pivotal Event*
CF = *Probability of Failure in the Cognition Pivotal Event*
CS = *Probability of Success in the Cognition Pivotal Event*
AF = *Probability of Failure in the Action Pivotal Event*
AS = *Probability of Success in the Action Pivotal Event*
FF = *Probability of Failure in the Feedback Pivotal Event*
FS = *Probability of Success in the Feedback Pivotal Event*
S = *Probability of a Successful Resolution of the Human Factors Triggering Event (HFTE)*
F = *Probability of a Failed Resolution of the Human Factors Triggering Event (HFTE)*

II. Introduction

An engineered system is comprised of numerous base level components and associated subsystems combined together into a larger and more complex system that is used to perform a useful function per a specified design intent. Of equal

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[1] Associate Professor, Department of Mechanical Engineering

[2] Department Chair & Woodward Professor, Department of Systems Engineering

importance in the system design, are human factors considerations. Human beings (human actors) often interact with a system in a number of ways, and can have a significant role in the reliability and safety of a system throughout the designated life-cycle. All of the components and subsystems that constitute complex systems have attributes and specific relationships with each other. These attributes and relationships, are responsible for the operational characteristics of the system, and are intended to meet the stated design requirements. These myriad of combined functionalities, and associated interactions, within the system lifecycle, must be modeled, analyzed, and documented as a matter of Systems Engineering (SE) best practice. Additionally, the reliability and hazard characteristics of the system design must be evaluated and analyzed, with all of the identified potential hazards eliminated or minimized such that a failure will not result in a catastrophic outcome. To be complete, this analysis must also consider the risk posed by human-system interactions. A consistent and uniform approach to analyzing the human contribution to safety throughout the system lifecycle design process is preferred.

The contemporary inductive perspective of a system safety analysis tends to emphasize scrutiny of the elements (electrical, mechanical, software) that are combined into the larger system architecture [1]. Typically, the probabilistic failure rates of these various elements are determined, and then accounted for in the larger system arrangement using established Hazard Analysis Techniques (HAT's). The prospective failure modes and safety related concerns of a system are evaluated based on the results of these HAT activities and documented for future abatement during subsequent design and testing activities [1]. In addition to the electrical, mechanical, and software elements that are commonly recognized as the core building blocks of a system design, human beings, and their respective influence on system operations, can be of equal, or even greater importance, to the performance, reliability, and safety within system lifecycle management. Accident rates attributable to human activity in system operations range from 10% to as high as 80% depending on the industry and application [2][8]. Although sometimes overlooked or minimized during system analysis and design, the various human interactions within the system context, and their possible impact on safety, should be properly scrutinized, with potential hazard probabilities being quantified alongside the other system elements being analyzed [8].

At present, there is no single, standardized, and universal technique to evaluate the hazards associated with human-system interaction [2][6]. Several Human Reliability Analysis (HRA) approaches have been developed over the past half century, but none have simple implementation and broad application across a large spectrum of system design scenarios [9]. Most of these HRA approaches have specific application relative to certain industries, environments, or operational activities [2].

An improved approach to human factors safety analysis, that determines Human Error Probability (HEP), and then communicates that information into a higher-level probabilistic model for overall hazard assessment, would be beneficial in the discipline of Systems Engineering (SE). The proposed Human Factors Hazard Model (HFHM) is intended to provide a standardized, automated, and efficient approach to assessing system risk associated with human interaction. With this new approach to predicting human hazard probability, comprehensive safety analysis of an entire system can be performed with improved accuracy, consistency of approach, and thoroughness.

III. System Safety Analysis and Human Reliability Analysis (HRA)

System safety analysis as an activity within Systems Engineering (SE) has its origins in the early 1960's, with the earliest contributor being the Department of Defense (DOD) with the standard practice specifications MIL-STD-38130 and MIL-STD-882 [1]. These standards are the original guiding directives for safety analysis. Following the development of these guidelines, other agencies that were quick to adopt these system safety philosophies included the Nuclear Regulatory Commission (NRC), as well as the National Aeronautics and Space Administration (NASA). Over the ensuing decades, these original methods of safety analysis, and many other new techniques, have gained widespread acceptance and use across numerous government agencies and commercial industries. In the modern era, it is very common for government agencies as well as industries in the private sector to perform detailed safety analysis using one or more of the various analysis techniques that have been developed. Due to the evolution of system safety analysis techniques over the past 50+ years, several commonly utilized Hazard Analysis Techniques (HAT's) have been established, and are now in wide use. Over 100 different HAT approaches are listed in The System Safety Analysis Handbook published by the International System Safety Society (ISSS) [1]. However, only 10-20 different HAT's are regularly used by system safety experts [1]. Among the most common HAT approaches utilized in safety analysis include Fault Tree Analysis (FTA) and Event Tree Analysis (ETA). Both of these approaches are based on deductive logic, quantitative analysis, and are considered to be a primary analysis method for safety and reliability analysis [1]. The FTA was developed and first used by Watson and Means of Bell Labs for reliability analysis related to the Minuteman missile guidance system. It was further developed by Boeing for used in evaluating the safety and reliability of the entire Intercontinental Ballistic Missile (ICBM) system. The ETA's historical background lies in the WASH-1400 studies that resulted in the Nuclear Regulatory Commission (NRC) reactor safety study report. ETA was developed to relate FTA results in a more organized and manageable way. Both FTA and ETA have direct application in Probabilistic Risk Assessment (PRA) and are used extensively to evaluate the likelihood of failure related to system design. Correspondingly, these two HAT's are used as a significant component of the analytical basis for the proposed Human Factors Hazard Model (HFHM) described in this work.

As an overview, FTA is used to combine the failure probability of basic events into larger logic networks, accounting for the interdependency and combined probability of failure, establishing intermediate failure probabilities [1]. These intermediate events are then combined to determine the likelihood of a top-level failure. All FTA's are composed of basic triggering events that are combined using AND/OR logic gates into intermediate events. These intermediate events are then combined using the same logic gate approach to determine the probability of the top-level undesired event. The FTA approach is very useful for evaluating the overall likelihood of a particular hazard with a quantified occurrence probability. The FTA results can then be used in subsequent safety analysis activities to assess the hazard event severity and possible negative consequences of the failure.

An ETA is used to evaluate a sequence of independent, but related events, and their subsequent probability of concluding in a hazardous event [1]. The primary purpose of an ETA is to determine the probability that a series of sequential pivotal events will culminate in success or failure. For the events identified and analyzed using ETA, the probabilities of all possible outcomes (success or failure) are evaluated and documented.

As with the hazard risk evaluation of traditional electro-mechanical system elements, the consideration of human factors, and its relationship to system safety has been studied for several decades. The first efforts to evaluate and quantify the effects of human interaction with a system began in the 1970's [2]. As a field of study, Human Reliability Analysis (HRA) is conducted with the intent of describing human interactions with the associated system elements, and describing the associated risks and potential failure modes. HRA is also intended to help develop corrective actions and other possible countermeasures intended to reduce or eliminate the possibility of human caused failures. Over the past several decades, many HRA techniques have been developed and put into common usage. There are currently 38 documented HRA methodologies in the public domain [2]. Among the most commonly utilized HRA techniques are the Technique for Human Error Prediction (THERP) and Expert Estimation [2].

THERP is one of the more commonly used and referenced HRA techniques. It was developed for application in safety analysis related to nuclear power plant operations [3]. THERP includes well defined procedural steps to hazard analysis, as well as a comprehensive library of Human Error Probabilities (HEP) associated with common human-system interactions. These documented HEP values include such activities as training efficacy, instrumentation interpretation, control system actuation, as well as other common human factors considerations such as fatigue and stress effects and their influence on HEP.

Expert Estimation or Expert Judgement is a general HRA approach with several different basic techniques used to assess HEP values associated with specific human-system interaction. Four basic approaches used for Expert Estimation have been documented, and they include: (1) paired comparison, (2) ranking / rating, (3) direct numerical estimation, and (4) indirect numerical estimation. Paired comparison and ranking / rating approaches produce equivocal results. Indirect numerical estimation will establish a HEP by relative comparison based on the probabilities of failure determined for other events. The direct numerical estimation technique produces a specific HEP based on an expert or group of expert's estimations of the likelihood of a specific error due to the relevant human factors as well as system characteristics [2][4].

IV. Human Error Probability (HEP) Modeling and Performance Shaping Factors (PSF)

The likelihood of a human actor reacting incorrectly to an operational scenario, thus resulting in a mishap, is referred to as Human Error Probability (HEP). The development of an analytical model used to predict HEP is primarily dependent upon two factors: (1) human factors and (2) system characteristics. These elements are referred to as Performance Shaping Factors (PSF) which are used to establish HEP relevant to various operational scenarios. For example, the complexity of a given system design, the human actor's knowledge of system operation, and the nature of the off-design functionality, will all contribute to the probability that the actor will react correctly to the errant system behavior, and successfully avoid a mishap. Some elements that represent human factors in PSF's are:

- Training
- Practice
- Experience
- Mental Acuity and Intellectual Capacity
- Gross and Fine Motor Skills
- Sensory Acuity (Vision, Hearing, Smell, Touch)
- Fatigue
- Impairment Level
- Stress and Emotional Stability
- Reaction Time
- Actor Location and Orientation in System Context
- Negligent or Malevolent Intent

Some elements that represent system characteristics in PSF's are:

- System Complexity
- Hazard Event Duration and Timing
- Observability of System Behavior
- Annunciation of Errant Behavior / Alarms
- Available Instrumentation to Monitor System Behavior
- Input Control Capabilities
- Input Control Accessibility
- Environmental Factors (Hot, Cold, Vibrations, Work Area Illumination, etc.)
- Fail Safes and / or System Safeguards

These PSF's (and others) are then used to develop the conditional and combined probabilities of failure that result in the HEP values used in the analysis. These established HEP values are then included in an analytical model used to produce a prediction of failure related to a given hazard scenario including both the system and associated human actor. As a general note, the values contributing to the HEP calculations can be used in their baseline state, or can be modified based on other contributing characteristics. For example, a baseline reaction time for a typical human actor can be adjusted by a multiplier depending on certain other PSF's. This may include such considerations as the actor's age, level of fatigue, distraction level. In this particular case, an example of the calculation of the adjusted reaction time would be of the form:

$$T_{AR} = (T_R)(M_A)(M_F)(M_D)$$

From the adjusted reaction time calculated above, a typical failure probability can be evaluated using HEP source data, expert estimation, or unique failure probability specifically determined by the safety analyst for the case at hand. All of the basic event probabilities determined in the human factors model using PSF's will follow similar contributing factor adjustments, conditional logic, and combined probability calculations to accurately represent the likelihood of a failure for that particular event.

V. A Human Factors Hazard Model (HFHM) for Human Reliability Analysis (HRA)

The proposed Human Factors Hazard Model (HFHM) is intended to predict the likelihood of failure due to a human actor's response to a Human Factors Triggering Event (HFTE). Where the HFTE is defined as any interaction between a human being and a system which may result in a mishap. The basic model of the steps involved in predicting the human response to an HFTE is a serial processing approach such that the event must first be perceived and recognized as a hazard. The actor will then process the available observed information, and then devise a possible corrective action. A remedial action by the actor is then communicated to the system via control inputs, and the subsequent system behavior response is then observed. Based on this system feedback behavior, the actor must decide whether to terminate control input as the hazard has been resolved, or continue to provide additional control input in an effort to eliminate the hazardous behavior. A schematic illustrating this hazard reaction model is presented in **Fig. 1**.

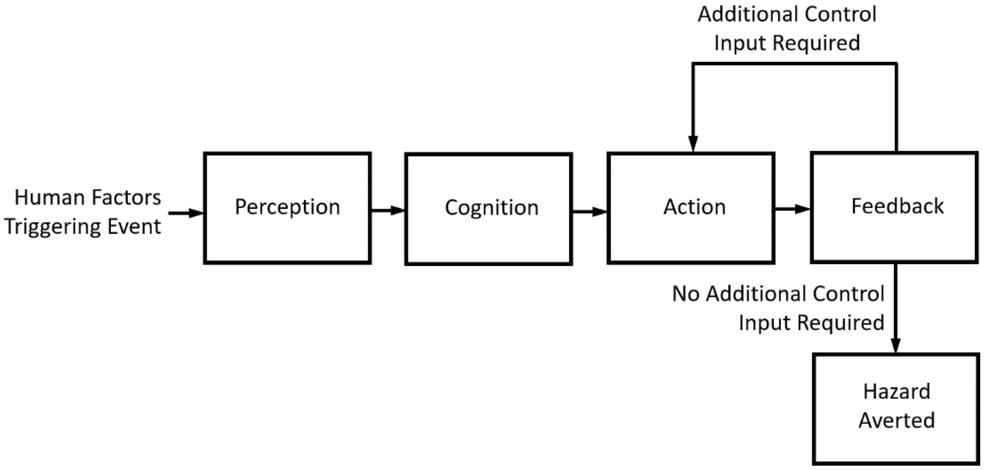


Fig. 1 HFTE Actor Processing Model

Each pivotal event noted above, namely: Perception, Cognition, Action, and Feedback, indicates a point in the hazard sequence where a possible failure could result in a mishap. For example, if the actor perceives the hazard event correctly, but then does not cognitively process it, arriving at a suitable corrective action, the series of events will not progress to the action step, and thus, the HFTE will end in a mishap. Each individual pivotal event noted is modeled using a Fault Tree Analysis (FTA). The top-level probability of failure, as noted in the FTA, corresponds to the likelihood of each pivotal event in the model process described above. The probability of success (or failure) for each of the four pivotal events are predicted via the FTA logic networks composed of basic events determined from the human factors and system characteristics unique to the problem being analyzed. The individual FTA's are each based on an evaluation of probability of failure associated with combinations of the various contributing events due to human interaction with the system. Each lower-level event probability of failure is evaluated using Boolean logic to arrive at a combined higher-level probability of failure. The two logic operators used in the FTA approach are the "AND" gate, which indicates that all events must occur for a true condition to occur, and the "OR" gate, which indicates that any or all events will precipitate a true condition. In the case of the "AND" logic, the corresponding Venn Diagram illustrating the joint probability of an event is presented in **Fig. 2**.

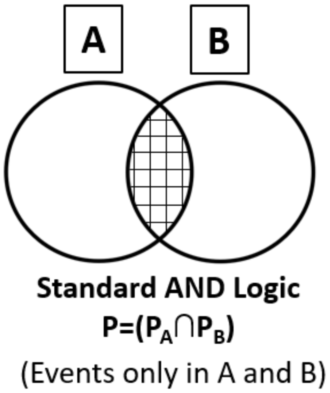


Fig. 2 AND Logic Venn Diagram

When applying the “AND” gate logic in an FTA network, each contributing event will have an associated probability of failure that are all accounted for in a single logic gate. The logic gate represents the associated Boolean operation to be performed on the contributing elements. This is illustrated in the schematic presented in **Fig. 3**.

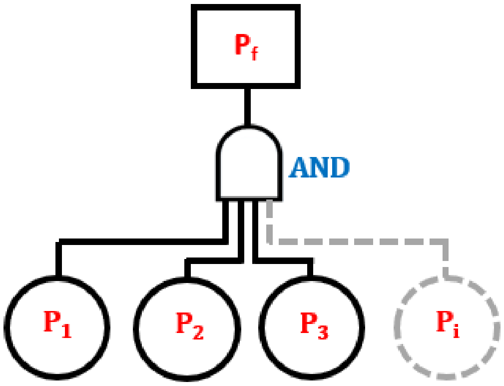


Fig. 3 Fault Tree Analysis AND Logic Schematic

The mathematical approach used to calculate the combined probability due to the “AND” logic gate as illustrated above is noted by the equation:

$$P_f = \prod_{n=1}^{i} P_n$$

In the case of the “OR” gate, a specific version of logic is applied in the combined probability. For the FTA approach used in this analysis, an “Inclusive OR” is utilized. In this type of Boolean logic, a single event, any combination of events, or all events associated with the higher-level event will satisfy the operator, thus resulting in a true condition. In the case of an “Inclusive OR” gate, the corresponding Venn Diagram illustrating the joint probability of an event is presented in **Fig. 4**.

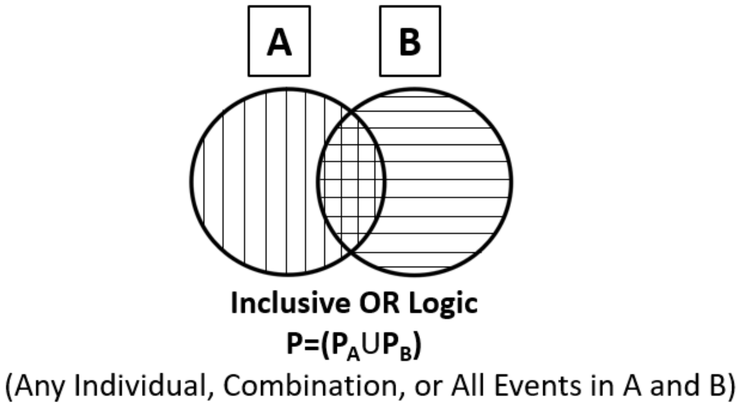


Fig. 4 Inclusive OR Logic Venn Diagram

When applying the "Inclusive OR" gate logic in an FTA context, each contributing event will have an associated probability of failure that all converge in a single logic gate. This logic gate represents the associated Boolean operation to be performed on the contributing probabilities. This is illustrated in the schematic presented in **Fig. 5**.

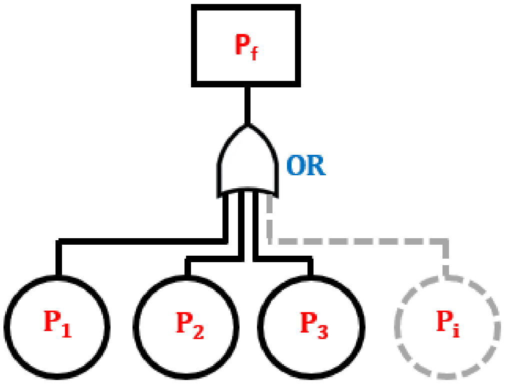


Fig. 5 Fault Tree Analysis Inclusive OR Logic Schematic

The mathematical approach used to calculate the combined probability due to the "Inclusive OR" logic gate as illustrated is noted by the equation:

$$P_f = \sum_{n=1}^{i} (-1)^{n+1} \left[\sum \left(\prod \left[CP_n \right) \right] \right.$$

As an example of "Inclusive OR" logic and the associate mathematics, consider a scenario with four contributing events (P_1, P_2, P_3, P_4). The equation to calculate the combined probability (P_f) of the intermediate event is:

$$\begin{aligned} P_f = (P_1 + P_2 + P_3 + P_4) \\ - [(P_1)(P_2) + (P_1)(P_3) + (P_1)(P_4) + (P_2)(P_3) + (P_2)(P_4) + (P_3)(P_4)] \\ + [(P_1)(P_2)(P_3) + (P_1)(P_2)(P_4) + (P_1)(P_3)(P_4) + (P_2)(P_3)(P_4)] \\ - [(P_1)(P_2)(P_3)(P_4)] \end{aligned}$$

Where the intermediate combined failure (P_f) is the alternating sign sum of the product of each incremental combination of contributing events (P_1, P_2, P_3, P_4).

As previously described, each pivotal event contributing to the human actor response to an HFTE has a corresponding FTA that establishes the Human Error Probability (HEP) related to that event. An example of the FTA related to the Perception pivotal event is presented in **Fig. 6** and **Tab. 1**.

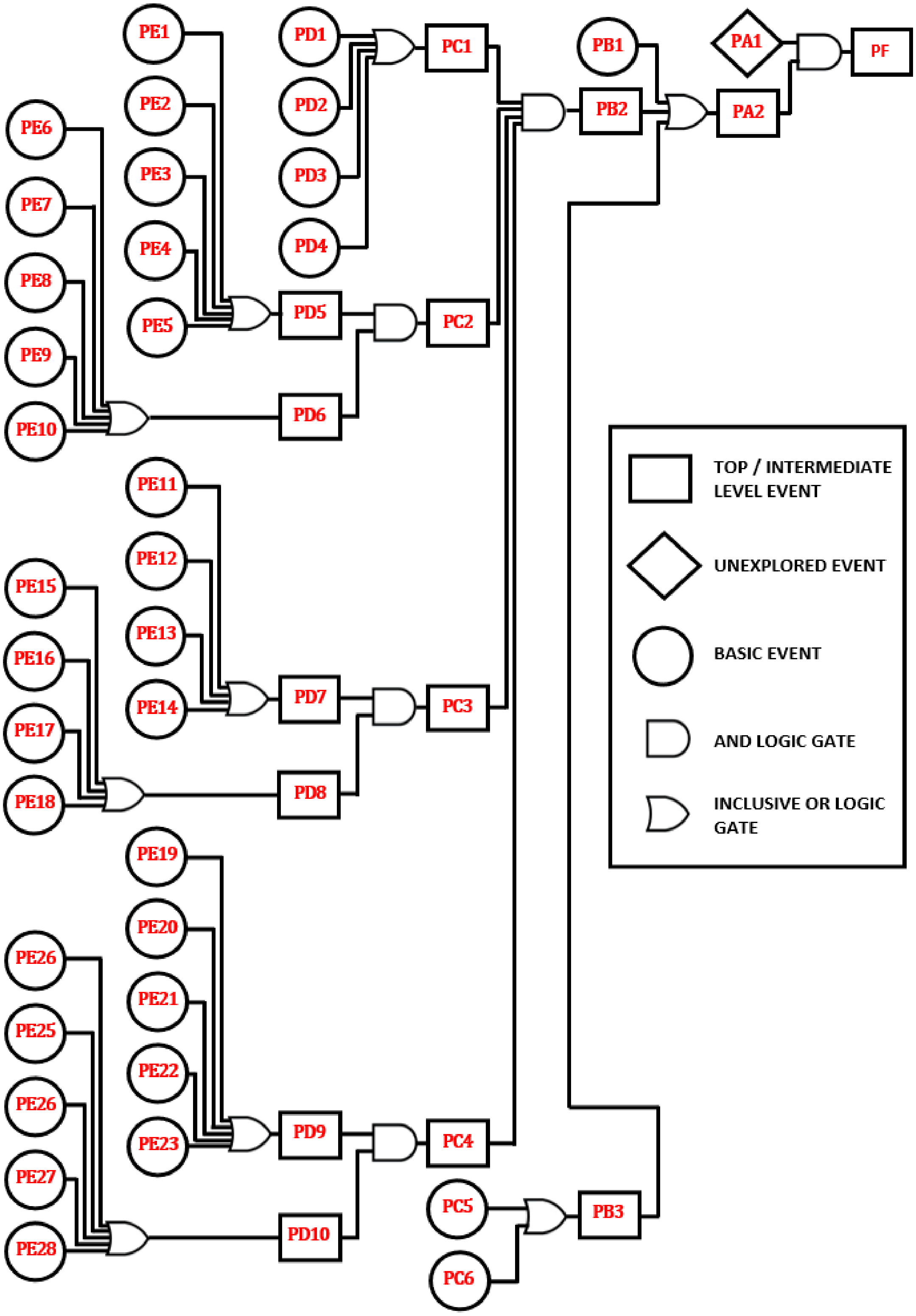
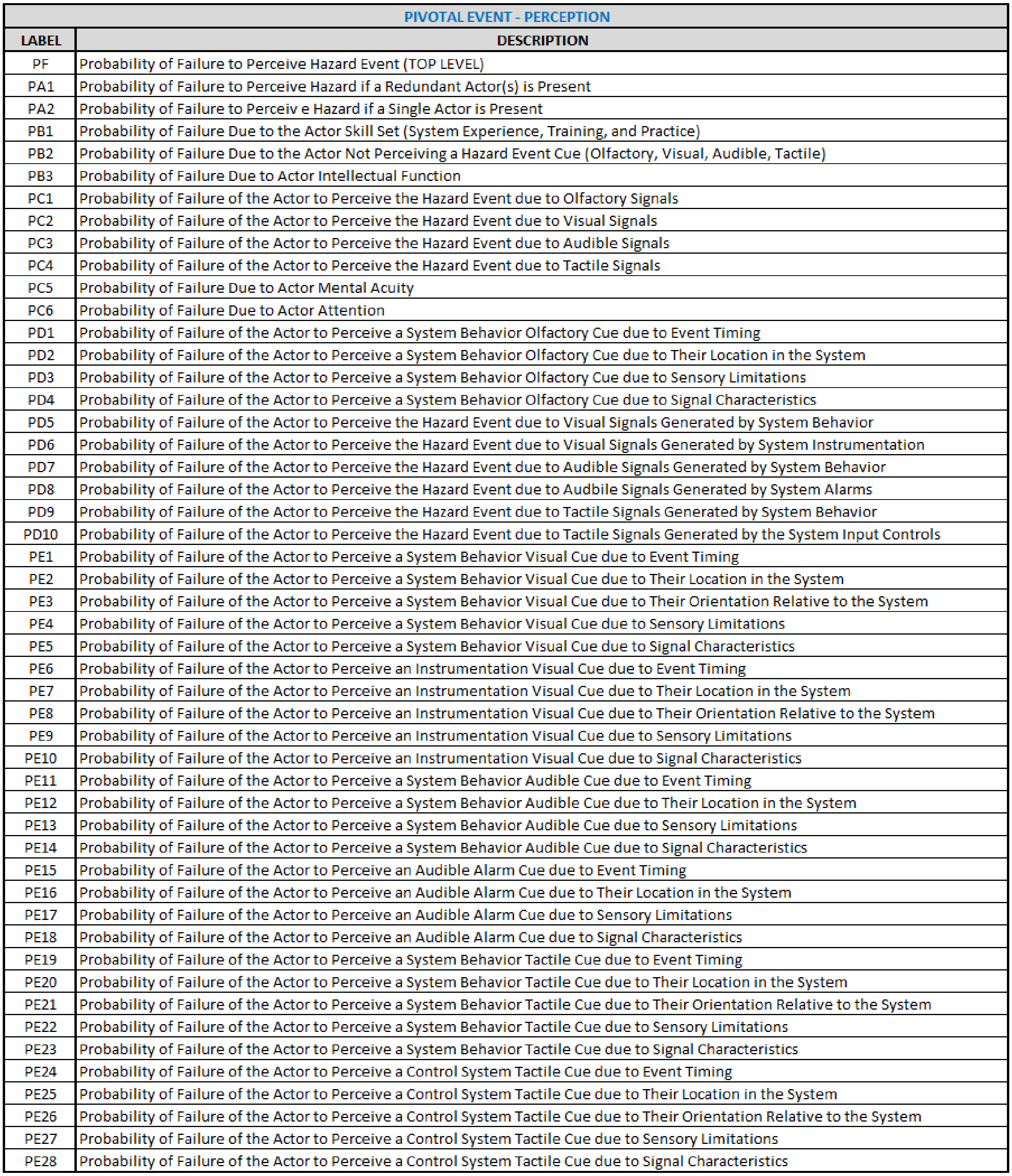


Fig. 6 Perception Pivotal Event FTA Logic Network



PIVOTAL EVENT - PERCEPTION	
LABEL	**DESCRIPTION**
PF	Probability of Failure to Perceive Hazard Event (TOP LEVEL)
PA1	Probability of Failure to Perceive Hazard if a Redundant Actor(s) is Present
PA2	Probability of Failure to Perceiv e Hazard if a Single Actor is Present
PB1	Probability of Failure Due to the Actor Skill Set (System Experience, Training, and Practice)
PB2	Probability of Failure Due to the Actor Not Perceiving a Hazard Event Cue (Olfactory, Visual, Audible, Tactile)
PB3	Probability of Failure Due to Actor Intellectual Function
PC1	Probability of Failure of the Actor to Perceive the Hazard Event due to Olfactory Signals
PC2	Probability of Failure of the Actor to Perceive the Hazard Event due to Visual Signals
PC3	Probability of Failure of the Actor to Perceive the Hazard Event due to Audible Signals
PC4	Probability of Failure of the Actor to Perceive the Hazard Event due to Tactile Signals
PC5	Probability of Failure Due to Actor Mental Acuity
PC6	Probability of Failure Due to Actor Attention
PD1	Probability of Failure of the Actor to Perceive a System Behavior Olfactory Cue due to Event Timing
PD2	Probability of Failure of the Actor to Perceive a System Behavior Olfactory Cue due to Their Location in the System
PD3	Probability of Failure of the Actor to Perceive a System Behavior Olfactory Cue due to Sensory Limitations
PD4	Probability of Failure of the Actor to Perceive a System Behavior Olfactory Cue due to Signal Characteristics
PD5	Probability of Failure of the Actor to Perceive the Hazard Event due to Visual Signals Generated by System Behavior
PD6	Probability of Failure of the Actor to Perceive the Hazard Event due to Visual Signals Generated by System Instrumentation
PD7	Probability of Failure of the Actor to Perceive the Hazard Event due to Audible Signals Generated by System Behavior
PD8	Probability of Failure of the Actor to Perceive the Hazard Event due to Audbile Signals Generated by System Alarms
PD9	Probability of Failure of the Actor to Perceive the Hazard Event due to Tactile Signals Generated by System Behavior
PD10	Probability of Failure of the Actor to Perceive the Hazard Event due to Tactile Signals Generated by the System Input Controls
PE1	Probability of Failure of the Actor to Perceive a System Behavior Visual Cue due to Event Timing
PE2	Probability of Failure of the Actor to Perceive a System Behavior Visual Cue due to Their Location in the System
PE3	Probability of Failure of the Actor to Perceive a System Behavior Visual Cue due to Their Orientation Relative to the System
PE4	Probability of Failure of the Actor to Perceive a System Behavior Visual Cue due to Sensory Limitations
PE5	Probability of Failure of the Actor to Perceive a System Behavior Visual Cue due to Signal Characteristics
PE6	Probability of Failure of the Actor to Perceive an Instrumentation Visual Cue due to Event Timing
PE7	Probability of Failure of the Actor to Perceive an Instrumentation Visual Cue due to Their Location in the System
PE8	Probability of Failure of the Actor to Perceive an Instrumentation Visual Cue due to Their Orientation Relative to the System
PE9	Probability of Failure of the Actor to Perceive an Instrumentation Visual Cue due to Sensory Limitations
PE10	Probability of Failure of the Actor to Perceive an Instrumentation Visual Cue due to Signal Characteristics
PE11	Probability of Failure of the Actor to Perceive a System Behavior Audible Cue due to Event Timing
PE12	Probability of Failure of the Actor to Perceive a System Behavior Audible Cue due to Their Location in the System
PE13	Probability of Failure of the Actor to Perceive a System Behavior Audible Cue due to Sensory Limitations
PE14	Probability of Failure of the Actor to Perceive a System Behavior Audible Cue due to Signal Characteristics
PE15	Probability of Failure of the Actor to Perceive an Audible Alarm Cue due to Event Timing
PE16	Probability of Failure of the Actor to Perceive an Audible Alarm Cue due to Their Location in the System
PE17	Probability of Failure of the Actor to Perceive an Audible Alarm Cue due to Sensory Limitations
PE18	Probability of Failure of the Actor to Perceive an Audible Alarm Cue due to Signal Characteristics
PE19	Probability of Failure of the Actor to Perceive a System Behavior Tactile Cue due to Event Timing
PE20	Probability of Failure of the Actor to Perceive a System Behavior Tactile Cue due to Their Location in the System
PE21	Probability of Failure of the Actor to Perceive a System Behavior Tactile Cue due to Their Orientation Relative to the System
PE22	Probability of Failure of the Actor to Perceive a System Behavior Tactile Cue due to Sensory Limitations
PE23	Probability of Failure of the Actor to Perceive a System Behavior Tactile Cue due to Signal Characteristics
PE24	Probability of Failure of the Actor to Perceive a Control System Tactile Cue due to Event Timing
PE25	Probability of Failure of the Actor to Perceive a Control System Tactile Cue due to Their Location in the System
PE26	Probability of Failure of the Actor to Perceive a Control System Tactile Cue due to Their Orientation Relative to the System
PE27	Probability of Failure of the Actor to Perceive a Control System Tactile Cue due to Sensory Limitations
PE28	Probability of Failure of the Actor to Perceive a Control System Tactile Cue due to Signal Characteristics

Tab. 1 Perception FTA Event Descriptions

As noted, similar FTA networks can be used to predict the probability of failure of the other three pivotal events, namely: Cognition, Action, and Feedback. The four FTA logic networks are designed to calculate the associated probability of failure for the top-level event in the analysis based on the base level HEP values and all intermediate probabilities calculated in the logic network. The corresponding probability of success (PS) given each FTA probability of failure (PF) is calculated using:

$$PS = 1 - PF$$

Each pivotal event FTA is used to specify the corresponding probability of success and failure into an Event Tree Analysis (ETA). The event tree then calculates the probability of each sequential event occurring in successive order. The logical basis of the ETA calculation assumes that each pivotal event must occur without failure in order for an ultimate successful outcome. In the case of the HFHM, all four events must successfully occur sequentially for the HFTE to be resolved. If any individual pivotal event experiences a failure, then all subsequent events are null, and the HFTE has resulted in a mishap. Per this logic, each individual pivotal event is considered to be mutually exclusive in that any individual failure precludes success for all subsequent events. The logic network and associated mathematical basis of the ETA is presented in **Fig. 7**.

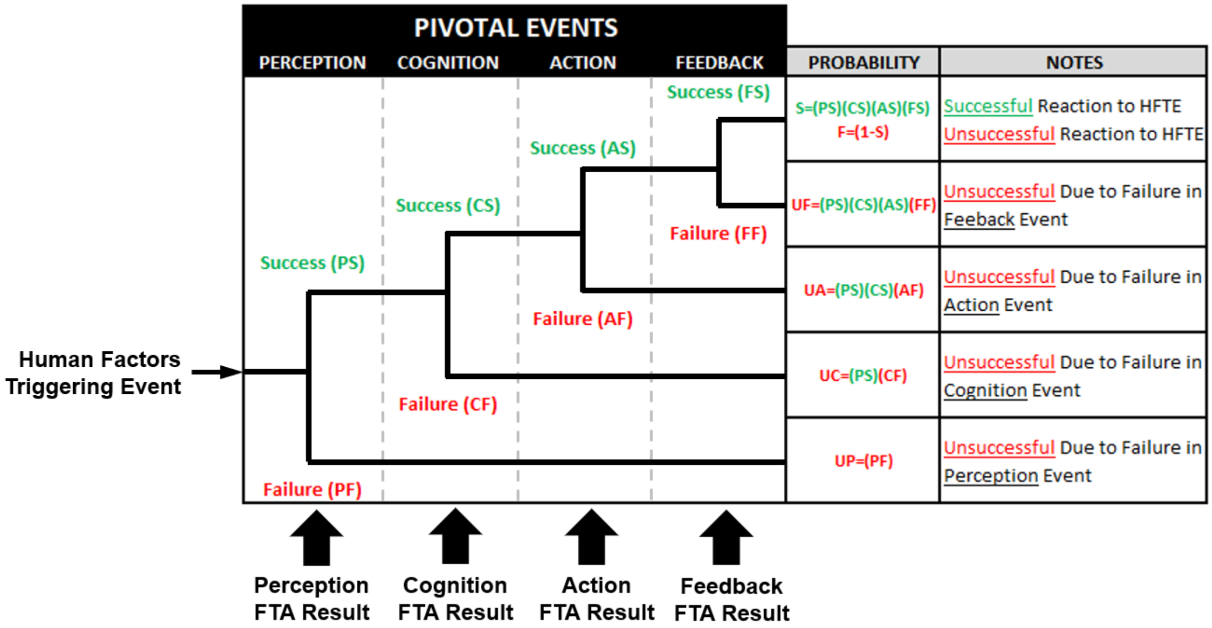


Fig. 7 HFTE Sequential Processing Model ETA

In addition to the FTA/ETA component of the HFHM, a unique computational approach has been developed to determine Performance Shaping Factors (PSF's) and the associated HEP's. The HEP values are then used to establish the basic event probabilities that are utilized at the bottom levels of the four FTA networks. The PSF and HEP values are calculated using the human factors unique to the anticipated actor, and system characteristics specific to the system architecture. In cases where the human factors and system characteristics are considered to be standard and universally applicable, the HEP values can be derived from existing literature [3][5]. When certain PSF values are more random in nature and standard values are not universally established or published, the HEP values can be based on an Expert Estimation approach [4]. In addition to a standard Expert Estimation approach with specified probability ranges, the HFHM model is also designed with a level of flexibility, such that custom probabilities of failure and their associated statistical uncertainty can be specified based on user generated empirical data for specific operational scenarios.

As noted in the description of the proposed HFHM, a large number of calculations are required to establish the PSF's and associated HEP values that feed into the individual FTA models. Additionally, the associated quantity of calculations required to establish all intermediate and top-level probabilities in the FTA and ETA networks are also voluminous. Therefore, any attempt to perform these calculations by hand would take a large amount of time, and would most likely be prone to errors. Additionally, any requirement to perform design or sensitivity studies by arbitrarily changing individual parameters, to evaluate the effect of various operational scenarios, would prove very problematic in returning accurate and timely results. For this reason, the proposed HFHM is intended to be automated using a computational platform. Microsoft Excel, the standard MS Office spreadsheet software, has been selected to be the basis of the HFHM model. This decision was made for several reasons. First, MS Excel is commonly available on the vast majority of computers, second, most users are familiar with the basic functionality of the software, and have operational experience, third, the software has the programming and computational power required to perform the required calculations of the HFHM, and fourth, the software has an intuitive, user friendly interface, and can present information in a logical and easy to understand format.

VI. Conclusions and Developmental Status

Although human behavior is commonly thought of as difficult to predict, the proposed Human Factors Hazard Model (HFHM) is a step in the direction of providing a simplified, standardized, and repeatable approach to assessing human error probabilities, and their relationship to mishaps. The model is based on established error probabilities and human performance characteristics that have been experimentally derived over the past several decades. The model also makes allowances for expert estimation or empirical data to be combined or substituted for Human Error Probability (HEP) data embedded in the base functionality. The automated nature of the model allows for design and sensitivity studies to be quickly and efficiently performed. Results of hazard analysis are standardized, and can be easily documented for a consistency in reporting throughout a system lifecycle timeline.

As of the publishing of this paper, the HFHM is nearly complete and ready for deployment for testing and evaluation. There are several industry reviewers that have volunteered to test and evaluate the model. They will be providing feedback regarding its utility, value to system safety design, and any revisions or modifications that may improve it. Additional reviewers would be welcome as an added validation of the model and its utility in the field of System Engineering (SE), and specifically system safety analysis.

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