Approach to Performing Treatment of Important Human Actions for SMART

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1. Introduction

The Human Reliability Analysis (HRA) element in the Human Factors Engineering (HFE) program was expanded to address important Human Actions (HAs) that are deterministically identified, as well as those that have been identified using risk analysis. Deterministic engineering analyses typically are completed as part of the suite of analysis in the Final Safety Analysis Report (FSAR)/Design Control Document (DCD) in Chapter 7, Instrumentation & Control, and 15, Transient and Accident analysis. These deterministic analyses often credit human actions. In light of this expanded scope, the element was renamed "Treatment of Important Human Actions." [1, 2]

As a result of expanded scope, the HAs most important to safety are identified via a combination of probabilistic and deterministic analysis, and then the identified important HAs are addressed when conducting the HFE program.

In this paper, the approach to performing the one of HFE elements, Treatment of Important Human Actions, for SMART is introduced.

2. Analysis Scope

The scope of treatment of important HAs for SMART is to (1) identify the important HAs and (2) consider the identified important HAs in designing the HFE aspect of the plant to minimize the likelihood of personnel error, and to help ensure that personnel can detect and recover from any errors that occur. The detail scope of treatment of important HAs for SMART is as follows.

- The important HAs are determined and listed by probabilistic and deterministic means.
  - Important HA1(IHA1): Risk-important HAs from SMART PRA activity are identified as Critical Operator Actions (COAs)
  - Important HA2 (IHA2): HAs that are credited in the analyses to prevent or mitigate the accident and transients are identified as Manual Operator Actions (MOAs)
  - Important HA3 (IHA3): HAs necessary for accomplishing the required safety function in Diversity and Defense in Depth (D3) analysis are identified as MOA.
- Following analysis with regard to the identified important HAs are performed in treatment of important HAs in order to specify how important HAs are addressed by the HFE program in Function Allocation, Task Analysis, HSI design, Procedure Development, Training Program Development and Human Factors Verification and Validation (HF V&V).
  - Identification of important HAs
  - Activity type categorization
  - Basic cognitive function analysis
  - Error mode identification
  - Consideration of Important HAs in HFE program elements

3. Methodology

3.1 Identification of Important HAs

The input list for implementing the treatment important HAs is derived mainly from risk-important HAs from SMART PRA activity, HAs that are credited in the analyses to prevent or mitigate the accident and transients, and HAs necessary for accomplishing the required safety function in D3 analysis.

3.2 Activity type categorization

The first step is to produce an activity list for the important HAs. This is basically an additional task description which lists the activity components of the important HAs being analyzed. The list of critical activities is shown in Table I. The activities according to the important HAs are analyzed and connected with four basic cognitive functions.

Table I: List of critical activities

Activity type	
CO-ORDINATE	IDENTIFY
COMMUNICATE	MAINTAIN
COMPARE	MONITOR
DIAGNOSE	OBSERVE
EVALUATE	RECORD
PLAN	REGULATE
VERIFY	SCAN
EXECUTE	

3.3 Basic cognitive function analysis

There are four basic areas of cognitive functions that have to do with observation, interpretation, planning, and execution [3]. Each typical cognitive activity related to the important HAs can then be described in terms of which of the four cognitive functions it requires. Table II shows the mapping table between four basic cognitive functions and critical activity. Using the Table II, the important HAs categorized by activity list are connected with four basic cognitive functions.

Table II Mapping table between four basic cognitive functions and critical activity

Activity type	Basic cognitive function			
	Observation	Interpretation	Planning	Execution
CO-ORDINATE			v	v
COMMUNICATE				v
⋮	⋮	⋮	⋮	⋮
REGULATE	v			v

3.4 Error mode identification

In order to identify the human error modes with regard to the important HAs, generic cognitive function failure model is used. Generic cognitive function failure model is shown in Table III. The process for determining human error modes is that (1) the activity type regarding the important HAs are determined by Table I, (2) the basic cognitive functions related to the determined activity types of the important HAs are analyzed by Table II, and (3) the human error modes are identified based on the basic cognitive functions of the important HAs.

Table III Generic cognitive function failures

Cognitive function	**Potential cognitive function failure**	
Observation errors	O1	Observation of wrong objective. A response is given to the wrong stimulus or event
	O2	Wrong identification made, due to e.g. a mistaken due or partial identification.
	O3	Observation not made (i.e., omission), overlooking a signal or a measurement.
Interpretation errors	I1	Faulty diagnosis, either wrong diagnosis or an incomplete diagnosis
	I2	Decision error, either not making a decision or making a wrong or incomplete decision
	I3	Delayed interpretation, i.e., not made in time.
Planning errors	P1	Priority error, as in selecting the wrong goal (intention)
	P2	Inadequate plan formulated, when the plan is either incomplete or directly wrong
Execution errors	E1	Execution of wrong type performed, with regard to force, distance, speed, or direction
	E2	Action performed at wrong time, either too early or too late
	E3	Action on wrong object (neighbor, similar or unrelated)
	E4	Action performed out of sequence, such as repetitions, jumps, and reversals
	E5	Action missed, not performed (i.e., omission), including the omission of the last action in a series.

3.5 Consideration of Important HAs in HFE program elements

To minimize the likelihood of human error and facilitate error detection and recovery capability, the important HAs are addressed during Function Allocation, TA, HSI design, Procedure Development, Training Program Development and HF V&V.

Activity type categorization, basic cognitive function analysis, and error mode identification process help consideration of important HAs in HFE program elements. Consideration of important HAs in HFE program elements focuses that identified important HAs are well applied to the applicable HFE program elements such as Function Allocation, TA, HSI design, Procedure Development, Training Program Development and HF V&V.

4. Results

4.1 Identification of Important HAs

The important HAs (IHA) identified from probabilistic and deterministic means were listed in Table IV.

Table IV Important HAs

	Important HAs	Category
1	Operator fails to manually trip a reactor by RPS	IHA 1
2	Operator fails to manually trip a reactor by DPS	IHA 1
3	Operator fails to manually generate PRHRAS within 3 hours	IHA 1
4	Operator fails to manually generate CMTAS within 3 hours	IHA 1
5	Operator fails to manually generate SITAS within 3 hours	IHA 1
6	Operator fails to manually generate CIAS within 8 hours	IHA 1
7	Operator fails to start Bleed Operation within	IHA 1

	3 hours	
8	Operator fails to initiate Emergency Boration within 1 hour	IHA 1
9	Operator fails to start RCS pressure control within 5 hours	IHA 1
10	Operator fails to manually generate CPRSAS	IHA 1
11	Operator fails to open CCW HE02 isol. V1010 / ESW supplying V1004/10	IHA 1
12	Operator fails to open CCWP discharge line manual valve V1004	IHA 1
13	Operator fails to start ADG	IHA 1
14	Operator fails to start Intake Structure AHU HV03 supply fan AH22	IHA 1
15	Operator fails to initiate shutdown cooling using CCWS	IHA 1
16	Operator fails to start RRWMS for SIT refill	IHA 1
17	Operator fails to start ECT refilling system	IHA 1
18	Operator fails to initiate containment backup spray	IHA 1
19	Operator fails to recovery containment isolation	IHA 1
20	Operator fails to initiate cavity flooding	IHA 1
21	Reactor trip - 60min. for increase in feedwater flow transient - 30min. for reactor coolant pump shaft break - 60min. for double-ended break of a letdown line outside reactor containment - 60min. for SGTR accident - 30min. for LOCA	IHA 3
22	FIV/MSIV close - 60min. for increase in feedwater flow transient - 60min. for SGTR accident	IHA 3
23	CMT isolation valve open - 30min. for LOCA	IHA 3
24	CVCSIV close - 30min. after reactor trip for Chemical and volume control system malfunction	IHA 3
25	LDLIV close - 60mim. for double-ended break of a letdown line outside reactor containment	IHA 3
26	RCP stop - 30min. for LOCA	IHA 3
27	DWSIV close - 40 min. after reactor trip (Modes 1, 2) for Inadvertent decrease in boron concentration in the reactor coolant - 40 min. after generation of high SRM ratio alarm (Modes 3~5) for Inadvertent decrease in boron concentration in the reactor coolant	IHA 3
28	CMT/SIT open and CVCS control - 40 min. after reactor trip (Modes 1, 2) for Inadvertent decrease in boron concentration in the reactor coolant - 40 min. after generation of high SRM ratio alarm (Modes 3~5) for Inadvertent decrease in boron concentration in the reactor coolant	IHA 3
29	FW flow control - 40 min. after reactor trip (Modes 1, 2) for Inadvertent decrease in boron concentration in the reactor coolant - 40 min. after generation of high SRM ratio alarm (Modes 3~5)for Inadvertent decrease in boron concentration in the reactor coolant	IHA 3

4.2 Consideration of Important HAs in HFE program elements

To minimize the likelihood of human error-detection and recovery capacity, the important HAs are addressed during the HFE program elements. In particular, the analysis process in Section 3.2 - 3.4 was utilized as input to the HFE program elements such as HSI design, procedure development, training program development, and HF V&V as shown in the Table V (as an example).

Table IV Consideration of Important HAs in HFE program elements

Important HAs	Consideration of Important HAs in HFE program elements		
	HSI design/Procedure/Training program development	TA/FA	HF V&V
Operator Fail to trip Rx Manually	**HSI design** Simplification of information display (ex. First-out alarm coding) **Procedure development** Describe the corresponding information in the **Training program development** -Coordinate individual roles	**FA** Function allocation for important HAs **TA** Task and HSI requirement identification for Important HAs	**HF V&V** Verification that the sampling of operational conditions includes the important HAs

5. Conclusions

Since the revision of NUREG-0711 (Revision 3), the scope and title of human reliability analysis in the element of HFE program were changed. In "Treatment of Important Human Actions", new approach is required to identify important HAs and consider them during the HFE program elements. The proposed approach will help the HFE analyst as the one of the analysis methodologies.

REFERENCES

[1] NUREG-0711, Rev.3, "Human Factors Engineering Program Review Model", 2012

[2] NUREG-0800, Rev.03, “Standard Review Plan, Chapter 18.0 Human Factors Engineering,” 2016
[3] E. Hollnagel, “Cognitive Reliability and Error Analysis Method,” Elsevier Science Ltd, 1998