

#### Section 4. Human Factors Issues

The issues presented in this section include those outlined in the Human Factors Program Plan (HFPP) and documented in NUREG-0985, Revision 1.<sup>1</sup> This plan describes the human factors-related work required to complete the NUREG-0660<sup>2</sup> human factors tasks as well as the additional human factors-related efforts, identified during implementation of NUREG-0660<sup>3</sup> tasks, that require NRC attention. The lead responsibility and a summary of the findings for each item listed in this section can be found in Table II of the Introduction.

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<sup>1</sup> NUREG-0985, "U.S. Nuclear Regulatory Commission Human Factors Program Plan," U.S. Nuclear Regulatory Commission, August 1983, (Rev. 1) September 1984, (Rev. 2) April 1986.

<sup>2</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

<sup>3</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

## Human Factors Program Plan

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### DESCRIPTION

The many investigations which followed the accident at TMI-2 identified the need to bring human factors considerations into the requirements and regulations for the design, construction, and operation of nuclear power plants. NUREG-0660<sup>4</sup> contains many items which address human factors concerns. The "U.S. Nuclear

Regulatory Commission Human Factors Program Plan," NUREG-0985,<sup>5</sup> was subsequently developed to provide a more current and comprehensive consideration of the outstanding human factors issues related to the design, operation, and maintenance of nuclear power plants. This plan describes: (1) the technical assistance and research activities planned to provide the technical bases for the reduction of the human-factors-related

tasks described in NUREG-0660,<sup>6</sup> and (2) the additional human factors efforts identified during implementation of the TMI Action Plan that should receive NRC attention. The HFPP identifies seven program elements: (1) Staffing and Qualification; (2) Training; (3) Licensing Examinations; (4) Procedures; (5) Management and Organization; (6) Man-Machine Interface; and (7) Human Reliability.

### PRIORITY DETERMINATION

The prioritization analysis was performed by PNL under contract to NRC. Details of the PNL analysis will be included in NUREG/CR-2800.<sup>7</sup>

To ascertain the risk reduction achievable by the elements in the plan, PNL polled a group of specialists representing various disciplines in the human factors and plant operations skills. These experts estimated the achievable reduction in human error rate that could be realized by the implementation of regulatory requirements and guidance which would come about as the solution of each individual program element.

Element 7, "Human Reliability," is viewed as an issue that does not directly relate to protecting the public health and safety or the environment. Rather, it is related to increasing the knowledge, certainty, and understanding

of the other human factors issues in order to increase confidence in assessing levels of safety and improving or maintaining the NRC capability to make independent assessments of safety. As a result, this element is a licensing issue.

Since the plan was developed specifically to address the interrelationship of human factors issues, the first six elements of the HFPP cannot be treated as mutually-exclusive elements. For example, the adequacy of procedures is affected by training, that is, training assists in the proper interpretation and understanding of

procedures. To account for this interdependency or overlap of the individual elements, PNL used four separate approaches to calculate the contribution of each element to a reduction in risk. Each of these

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<sup>4</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

<sup>5</sup> NUREG-0985, "U.S. Nuclear Regulatory Commission Human Factors Program Plan," U.S. Nuclear Regulatory Commission, August 1983, (Rev. 1) September 1984, (Rev. 2) April 1986.

<sup>6</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

<sup>7</sup> NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986, (Supplement 5) July 1996.

approaches accounts for overlaps by compiling the results of the questionnaire taken in the poll in a different way. No one approach is believed to accurately model the real overlap that exists between the various plan elements. The first approach simply considered that there were no overlaps between the various plan elements. The second approach considered that all overlaps of other elements (on the first element) were removed from the first element, and then all overlaps (of the first element) on the other elements were added to the remaining direct effect of the first element. The third approach considered overlap removal and addition based on an initial order of implementation. The fourth approach considered overlap removal and addition based on the most

incrementally efficient order of implementation. The reevaluation occurred after each element was implemented. These four approaches were intended to consider the various ways that element overlaps can be accounted for and how these ways affect improvement of human performance assessments.

*Frequency/Consequence Estimate*

The results of the questionnaire were used to calculate the risk change using the Oconee and Grand Gulf RSSMAP studies.<sup>8</sup> The overall reduction in human error value was estimated to be 60 percent. This is broken down into the six categories and models as shown in the interim results, Table 4.1. This overall value was applied to all operator error parameters in the Oconee and Grand Gulf risk assessments and the resulting risk changes were calculated. A risk change was calculated for each of the four dependency models identified

by A, B, C, and D. This risk change value is the total risk reduction which would result if all of the six plan elements were implemented. This risk change was multiplied by the individual elements rating to yield the risk change which could be attributed to each element by each dependency model as shown in Table 4.2. Based

on 90 PWRs and 44 BWRs with average lives of 28.8 years and 27.4 years, respectively, the total industry risk reduction by approach is given in Table 4.3.

*Cost Estimate*

The estimated costs involved in the HFPP were derived using the previously estimated costs of the human factors generic safety issues in the TMI Action Plan.<sup>9</sup> Each of the individual generic safety issues were examined to determine which issues were applicable to the program plan and assigned a percentage application to the HFPP and to specific HFPP elements as shown in Table 4.4.

Safety issue costs for NRC and utility development, implementation, and operation were examined and assigned to the different elements in the percentage weights previously determined. Costs associated with improving the plant maintenance program were removed since the maintenance improvement activity is to be prioritized as a separate program. However, maintenance costs (ongoing element costs) associated with keeping the element functional are included.

ELEMENT AREAS	RATINGS (%) BY APPROACH			
	A	B	C	D
<b>TABLE 4.1: INTERIM RESULTS BASED ON COMPILED QUESTIONNAIRE ANSWERS</b>				
Staffing and Qualifications	11.1	15.9	7.9	0.9

<sup>8</sup> NUREG/CR-1659, "Reactor Safety Study Methodology Applications Program," U.S. Nuclear Regulatory Commission, (Vol. 1) April 1981, (Vol. 2) May 1981, (Vol. 3) June 1982, (Vol. 4) November 1981

<sup>9</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

Training	22.3	21.7	32.8	41.6
Licensing Examinations	11.4	10.4	3.0	6.7
Procedures	18.6	16.1	17.1	9.0
Man-Machine Interfaces	17.7	10.9	3.4	14.9
Management and Organization	<b>18.9</b>	<b>25.1</b>	<b>35.8</b>	<b>26.9</b>
<b>TOTAL:</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

TABLE 4.2: RISK CHANGE RESULTS BASED ON INTERIM RATING RESULTS								
	RISK REDUCTIONS (MAN-REM/RY) BY APPROACH AND REACTOR TYPE							
	A		B		C		D	
ELEMENT AREAS	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR
Staffing and Qualifications	6.2	4.8	8.9	6.8	4.4	3.4	0.5	0.4
Training	12.5	9.6	12.2	9.3	18.4	14.1	23.3	17.9
Licensing Examinations	6.4	4.9	5.8	4.5	1.7	1.3	3.8	2.9
Procedures	10.4	8.0	9.0	6.9	9.6	7.4	5.0	3.9
Man-Machine Interfaces	9.9	7.6	6.1	4.7	1.9	1.5	8.3	6.4

TABLE 4.2: RISK CHANGE RESULTS BASED ON INTERIM RATING RESULTS								
Management and Organization	10.6	8.1	14.1	10.8	20.0	15.4	15.1	11.6
TOTAL:	56.0	43.0	56.1	43.0	56.0	43.1	56.0	43.1

TABLE 4.3: TOTAL INDUSTRY RISK CHANGE RESULTS				
	RISK REDUCTIONS BY APPROACH (10 <sup>4</sup> MAN-REM)			
ELEMENT AREAS	A	B	C	D
Staffing and Qualifications	2.2	3.1	1.6	0.18
Training	4.4	4.3	6.5	8.2
Licensing Examinations	2.2	2.0	0.6	1.3
Procedures	3.7	3.2	3.4	1.8
Man-Machine Interfaces	3.5	2.1	0.67	2.9
Management and Organization	3.7	5.0	7.0	5.3
TOTAL:	20	20	20	20

TABLE 4.4: ALLOCATION OF TMI ISSUES IMPACT AMONG HUMAN FACTORS PROGRAM ELEMENTS								
		% Scope						
Issue Number	Title	%H*	SQ	T	LE	P	MO	MMI
STAFFING AND QUALIFICATIONS (SQ)								
I.A.1.4	Operating Personnel and Staffing Long-Term Upgrades (Resolved)	-	0	0	0	0	0	0

I.A.2.2	Training and Qualification of Operations Personnel	50	50	25	25	0	0	0
I.A.3.3	Requirements for Operator Fitness	1s00	90	0	10	0	0	0
TRAINING (T)								



TABLE 4.4: ALLOCATION OF TMI ISSUES IMPACT AMONG HUMAN FACTORS PROGRAM ELEMENTS								
	Selected Transients							
MANAGEMENT AND ORGANIZATION (MO)								
I.B.1.1(1,2,3)	Management for Operations: Organization and Management of Long-Term Improvement	40	10	10	5	15	60	0

TABLE 4.4: ALLOCATION OF TMI ISSUES IMPACT AMONG HUMAN FACTORS PROGRAM ELEMENTS									
		% Scope							
Issue Number	Title	%H*	SQ	T	LE	P	MO	MMI	
STAFFING AND QUALIFICATIONS (SQ)									
I.A.1.4	Operating Personnel and Staffing Long-Term Upgrades (Resolved)	-	0	0	0	0	0	0	0
I.A.2.2	Training and Qualifications of Operating Personnel	50	50	25	25	0	0	0	0
I.A.3.3	Requirements for Operator Fitness	100	90	0	10	0	0	0	0

TRAINING (T)								
I.A.2.6(4)	Long-Term Upgrade of Training and Qualifications (Training Workshops)	100	0	100	0	0	0	0
I.A.2.6(6)	Nuclear Power Fundamentals for Operator Training (Resolved)	-	0	0	10	0	0	0
I.A.2.6.(1,2,3,5)	Simulators	100	57	0	10	10	0	5
I.A.2.7	Accreditation of Training Institutions	100	10	80	10	0	0	0
I.A.2.4	NRR Participation in Inspector Training	30	0	100	0	0	0	0
I.A.4.2	Long-Term Training Simulator Upgrade	100	0	50	0	25	0	25
LICENSING EXAMINATIONS (LE)								
1.A.3.4	Licensing of Additional Operations Personnel	25	20	0	70	0	10	0
I.A.3.2	Operator Licensing Program Changes (Resolved)	-	0	0	0	0	0	0
PROCEDURES (P)								
I.C.9	Long-Term Program Plan for Upgrading Procedures	100	0	15	15	70	0	0
I.C.1(4)	Confirmatory Analysis of Selected Transients	100	0	15	15	70	0	0
MANAGEMENT AND ORGANIZATION (MO)								
I.B.1.1(1,2,3,4,6)	Management for Operations: Organization and Management of Long-Term Improvements	40	10	10	5	15	60	0
II.J.3.1/II.J.3.2	Organization and Staffing to Oversee Design Construction	0	25	25	0	0	50	0
MAN-MACHINE INTERFACE (MMI)								
I.D.3	Safety System Status Monitoring	100	0	10	0	10	0	80
I.D.4	Control Room Design Standard	100	0	10	0	10	0	80
1.D.5(3,4,5)	Control Room Design: Improved Control Instrumentation Research	100	0	10	0	10	0	80
*Percentage of TMI Action Plan items in the HFPP:								
Issue I.A.2.2 scope includes maintenance and technician training, so it is assumed that only 50% of the costs identified are applicable to the other portions of the HFPP.								

Issue I.A.2.4 is primarily a licensing issue; only 30% actually addresses human factors operating issues.

Issue I.A.3.4 impacts primarily the licensing of personnel associated with maintenance operations. It is assumed that only 25% of the scope/costs apply to the HFPP.

Issue I.B.1.1(1,2,3,4,6) addresses issues classified as maintenance; hence, only 40% is assigned to the HFPP.

Issues II.J.3.1/II.J.3.2 are addressed towards improving management oversight during design and construction and, hence) have no connection with the HFPP.

The combined scope of all the previous human factors safety issues in the TMI Action Plan<sup>10</sup> was examined to see if it gave a comprehensive coverage of the stated goals of the individual HFPP elements. The possibility of duplication of effort among issues must also be considered.

As a first estimate, it was judged that the previous safety issues do in fact give a sufficient coverage of scope such that costs will be representative for the Staff and Qualification, Training) Licensing Examination, and Man- Machine Interface (MMI) program elements. Excessive overlap between issues was not readily apparent.

The Procedures element was covered by only two previous issues. However, its role in further development with training, and especially advanced control room design (MMI) was recognized. As a first estimate, the values in Table 4.4 will be used.

The Management and Organization element was judged to be lacking in coverage of scope as represented by the safety issues. Item II.J.3.1 especially had no input to this program; however, an issue could be drafted

along similar lines to ensure consideration of human factors associated problems in management circles during stages of design, construction, and modification. An approach similar to Item I.A.3.3 which involves NRR human factors input to OIE inspector training could also be applied to the training of engineers undergoing training to oversee design and construction. These engineers would then play a strong management role after construction, as with Issue II.J.3.1. This area has also been recently recognized as one where substantial commitment

and improvement on the part of utilities may be needed. As a result of this, it will be assumed that the costs identified by Issue II.J.3.1 will also be included here as representative of a similar type of program for increasing management awareness of human factors requirements in their organizational structure.

Table 4.5 presents estimates of the industry costs to implement the HFPP actions. Table 4.6 presents estimates of the NRC costs to establish regulatory requirements and to provide for annual review. The annual costs for the operation and maintenance of each program element was multiplied by 28.3 years, the average remaining plant life, to determine the lifetime costs.

Implementation of the HFPP elements is expected to result in cost savings due to a reduction in downtime and increased plant availability. However, the impact on plant availability could be expected to be more difficult to quantify the further the program moves away from hardware. Hence, while it is recognized that a cost saving will result from the implementation of the findings in the HFPP, the costs were not calculated.

<sup>10</sup> NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U.S. Nuclear Regulatory Commission, May 1980, (Rev. 1) August 1980.

*Value/Impact Assessment*

The value/impact ratios for each element and the total plan are presented in Table 4.7. The value/impact assessment is shown for each of the four approaches used to calculate the risk reduction. As shown in this table, the element scores range from 1.2 to 96 man-rem/\$M. The value/impact assessment for the entire plan was calculated to be 27 man-rem/\$M.

TABLE 4.7: SUMMARY OF RESULTS								
		HFPP ELEMENT						
		Staffing Qualification	Trainings	Licensing Examination	Procedures	Man-Machine Interface	Management Organization	Total
Public Risk (10 <sup>4</sup> man-rem)	A-	2.2	4.4	2.2	3.7	3.5	3.0	20
	B-	3.1	4.3	2.0	3.2	2.1	5.0	20
	C-	1.6	6.5	0.6	3.4	0.67	7.0	20
	D-	0.18	8.2	1.3	1.8	2.9	5.3	20
Total Cost Industry & NRC (\$M)		1500	2800	660	1000	690	730	7400
Assessment Value/Impact (man-rem/\$M)	A-	15	16	33	37	51	51	27
	B-	21	15	30	32	30	69	27
	C-	11	23	9.1	34	9.7	96	27
	D-	1.2	29	20	18	42	73	27

*Other Considerations*

The risk reduction calculation resulting from human error reduction considers only the reduction in human errors after the assumed initiation of an accident sequence. The PRA analyses on which these calculations are based do not give credit to a reduction in transient events due to improved operator capability, nor do they give credit for operator intervention to overcome hardware malfunctions. Further, the existing PRAs on which this analysis was based, in general, considered only the type of human errors classified as procedural errors. These acts are also often called the "skill and rule" based actions. Neglected in these PRA analyses are the cognitive acts of the operator which may be the most crucial. Thus, the contribution to risk reduction resulting from reducing human error is underestimated. The low value/impact assessments emphasize the necessity of carefully selecting regulatory requirements which will be most cost effective.

**CONCLUSION**

Depending upon the relative contribution of the other associated elements, a few of the elements of the HFPP might result in a medium priority ranking, but the uncertainty associated with the dependency calculations warrants assigning the major elements a high priority rating. Hence, a high priority ranking was assigned the HFPP and its major plan elements, except Element 7 which is a licensing issue. However, in June 1986, the

HFPP was reevaluated<sup>11</sup> and the 34 original issues were reduced to 27 issues, 11 of which were deemed to be licensing issues. A complete description of all HFPP issues and their priority are discussed further in this section.

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<sup>11</sup> Memorandum for J. Funches from F. Rowsome, "Handling of DHFT Issues in GIMCS," June 6, 1986. [8606120789]

