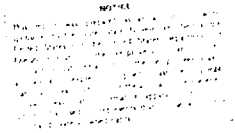


Alan D. Swain
Sandia Labs - 1223

September 12, 1978

SUMMARY OF PROJECT TO DEVELOP HANDBOOK OF HUMAN RELIABILITY ANALYSIS FOR NUCLEAR POWER PLANT OPERATIONS

For the past two years Alan Swain and Henry E. Guttmann, of the Statistics, Computing, and Human Factors Division, Sandia Laboratories, have been developing a handbook to aid qualified persons to evaluate the effect of human error on the availability of engineered safety systems and features in nuclear power plants. The handbook includes a mathematical model, procedures, derived human failure data, and principles of human behavior and ergonomics. The handbook is expanding the human error analyses which were presented in WASH-1400. The derived data represent generic human error probabilities with ranges of uncertainty which would be adequate for determination of the relative merits of different configurations of equipment, procedures, and operating practices within a plant, and for gross comparisons among plants.

The work, under the sponsorship of Probabilistic Analysis Staff, NRC Office of Nuclear Regulatory Research (Dr. M. C. Cullingford, NRC Program Manager), is about half completed. An outline of the handbook contents is given in copies of vugraphs (attached), followed by copies of human performance model abstractors (also attached). A first draft of the handbook is scheduled for NRC review by July 1, 1979.

References:

1. Swain, A. D. and Guttmann, H. E., "Human Reliability Analysis Applied to Nuclear Power," in Proceedings of the 14th Annual Reliability and Maintainability Conference, Inst. of Electrical and Electronic Engineers, New York, Jan. 1975, 116-119.

2. "Human Reliability Analysis," Section 6.1 in Appendix III - Failure Data, of WASH-1400 (NUREG-75/014): Reactor Safety Study - An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants, U. S. Nuclear Regulatory Commission, Wash., D.C., Oct. 1975, pp. III-59 - III-69.

3. Swain, A. D., "Estimating Human Error Rates and Their Effects on System Reliability," in Fiabilite et Disponibilite des Systemes Mecaniques et de Leurs Composants, Cycles de Conferences, Electricite de France - Commissariat a l'Energie Atomique, Jouy-en-Josas, France, Oct. 1977, Book 2, 31 pages.

4. Swain, A. D. and Guttmann, H. E., "Human Reliability Analysis of Dependent Events," in Probabilistic Analysis of Nuclear Reactor Safety, Nuclear Reactor Safety Division, American Nuclear Society, Los Angeles, May 1978, pp. X.2-1 - 12.

Alan D. Swain
Sandia Labs - 1223

September 12, 1978

Outline of 20 Minute Presentation (+ 10 minutes' discussion) for NRC talk on November 7, 1978 at National Bureau of Standards, Germantown, MD

Title: A Preview of the Handbook on Human Reliability Analysis of Nuclear Power Plant Operations

Handouts: Summary of Project to Develop Handbook of Human Reliability Analysis for Nuclear Power Plant Operations, including related references

Xerox copies of following slides by title:

1. Three Problems in HRA
2. Definitions of Human Reliability, Human Error, HER
3. The five categories of Human Error
4. "From a systems point of view"
5. List of chapters in the Handbook
6. List of chapters in the companion volume on data sources
7. Preliminary Formulation of Simulation Studies to Verify Models
8. Chapanis (1961) definition of a "model"
9. THERP use
10. THERP, steps in
11. Human Performance "Rules" to Date
12. Four Levels of Dependence
13. P(F) Given Different Dependence Levels
14. Walk-Around Detection of a Deviant Item
15. Curve showing % recovery by days after walk-around
16. Recovery of Walk-Around Efficiency
~~17. Recall of Special Instruction Items~~
18. Use of Checklist in Walk-Around Inspection
19. Hypothetical PDF
20. Hypothetical Cumulative Curve

THREE PROBLEMS IN HRA

1. ESTIMATE PROBABILITY OF PERFORMING EACH INTENDED TASK, AND DOING IT CORRECTLY.

2. ESTIMATE PROBABILITY OF PERFORMING SOME PARTICULAR ERRONEOUS ACTION.

3. NO FORMALIZED METHOD WHICH USES HUMAN PERFORMANCE DATA FROM A DATA BANK AND WHICH CAN BE USED BY AN ENGINEER TO DO HRA.

HUMAN RELIABILITY: The probability that a person

(1) correctly performs some system-required activity in a required time period (if time is a limiting factor), and

(2) performs no extraneous activity that can degrade the system.

HUMAN ERROR: Failure to perform the task correctly and/or within time limits, or performance of some extraneous activity that can degrade the system.

HUMAN ERROR RATE or HUMAN FAILURE PROBABILITY

= 1 - Human Reliability

which can be estimated as:

$$Pr\{F\} = \frac{\text{\# of errors of a given type}}{\text{\# of opportunities for this error}}$$

The five major categories of human error are:

1. When a person fails to perform a required action,

   an error of omission,

2. When he performs the required action incorrectly,

   an error of commission,

3. When he performs some action which should not have been performed,

   an extraneous action,

4. When he performs some required action out of sequence,

   a sequential error, or

5. When he fails to perform the action within the allotted time,

   a time error.

From a systems point of view,

A human action (or lack of action) is an error

only if it reduces or has the potential for reducing

some desired system function.

HANDBOOK OF HUMAN RELIABILITY ANALYSIS FOR NUCLEAR POWER PLANT OPERATIONS

HUMAN PERFORMANCE DATA RELATED TO NUCLEAR POWER PLANT OPERATIONS

PRELIMINARY FORMULATION OF SIMULATION STUDIES TO VERIFY HUMAN PERFORMANCE MODELS IN HANDBOOK

A. Safety-Related Tasks in Control Room
   1. Normal operating conditions
      a. Simulator studies
      b. LER data to "calibrate" simulator data
   2. Unusual (stressful) operating conditions (e.g., anticipated transients, LOCAs)
      a. Use of physiological measures in simulator studies
      b. Psychological scaling by "expert" judges

B. Safety-Related Tasks Outside Control Room
   1. Deliberately miss set plant status indications
      a. Use of actual equipment
      b. Use of simulated equipment
   2. Psychological scaling of "expert" opinion
   3. LER data to calibrate data from above two approaches

MODEL

A model of a system is an abstraction which reproduces (simulates) symbolically the way in which the system functions operationally.

Chapanis - 1961

THERP

Technique for Human Error Rate Prediction

Used to

Evaluate degradation to man-machine systems

Due to human errors in association with

Equipment functioning, operational procedures & practices

Other system & human events and characteristics

Which influence system behavior.

THERP
(Technique for Human Error Rate Prediction)

1. Define system (or part-system) failure.
2. Identify and list human operations performed and their relationships to system tasks and functions.
3. Predict error rates for each relevant human operation.
4. Determine effect of human errors on system failure rate.
5. Recommend changes to reduce system failure rate to an acceptable level and repeat steps 1-4.

HUMAN PERFORMANCE "RULES" TO DATE

- Dependence (coupling)
- Walk-Around Inspection
- Unavailability
- Displays in Control Room
- Annunciators
- Analog Displays (and Digital Readouts)
- Status Lamps
- Stress
- Recovery Factors
- Distributions
- Skill Level

FOUR LEVELS OF DEPENDENCE

ZERO (ZD) - Complete independence of activities

MODERATE (MD) - $\overline{G}$ of $Pr\{F|ZD\}$ and $Pr\{F|CD\}$

"Halfway" between ZD and CD

HIGH (HD) - $\overline{G}$ of $Pr\{F|MD\}$ and $Pr\{F|CD\}$

"Halfway" between MD and CD

COMPLETE (CD) - If one activity occurs,

the other(s) always occurs

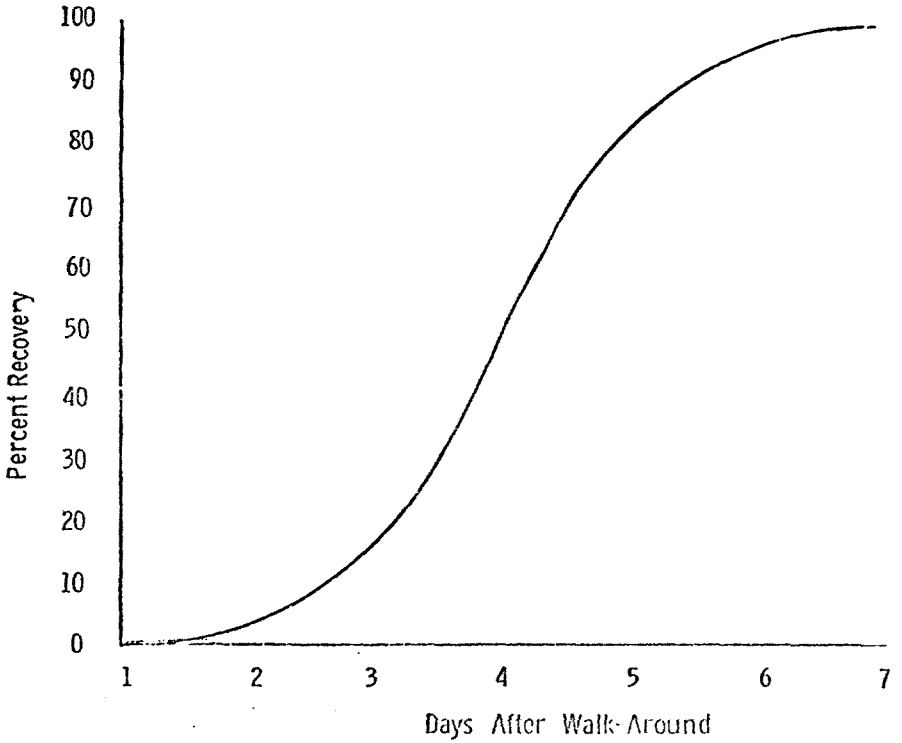
P(F) GIVEN DIFFERENT DEPENDENCE LEVELS

Parallel Systems		Series Systems
	ZERO	
$A \times B \times \ldots N$		$1 - a \times b \times \ldots n$
	COMPLETE	
I, where I is the HER for whichever event occurs first.		1 - i, where i is the P(S) for whichever event occurs first.
$\frac{A + B + \ldots N}{N}$, when the order of events is indefinite		$1 - \frac{a + b + \ldots n}{n}$, when the order of events is indefinite
	MODERATE	
$\left[P(F)\|CD \times P(F)\|ZD\right]^{\frac{1}{2}}$		$1 - \left[P(S)\|CD \times P(S)\|ZD\right]^{\frac{1}{2}}$
	HIGH	
$\left[P(F)\|CD \times P(F)\|MD\right]^{\frac{1}{2}}$		$1 - \left[P(S)\|CD \times P(S)\|MD\right]^{\frac{1}{2}}$
or $P(F)\|CD \left[\frac{P(F)\|ZD}{P(F)\|CD}\right]^{\frac{1}{4}}$		or $1 - P(S)\|CD \left[\frac{P(S)\|ZD}{P(S)\|CD}\right]^{\frac{1}{4}}$

WALK-AROUND DETECTION OF A DEVIANT ITEM

Days After Deviation Occurred	P(S)
1	.1
2	.05
3	.025
4	.001*
5 etc.	.001*

* Corrected from .000


100
90
80
70
60
50
40
30
20
10
0
Percent Recovery
1
2
3
4
5
6
7
Days After Walk-Around

RECOVERY OF WALK-AROUND EFFICIENCY
BY DAYS BETWEEN WALK-AROUND INSPECTIONS

Days	Z	% Recovery
1	-3.0	0.1
2	-2.0	2.3
3	-1.0	16
4	0	50
5	1.0	84
6	2.0	97.7
7	3.0	99.9

USE OF CHECKLIST IN WALK-AROUND INSPECTION

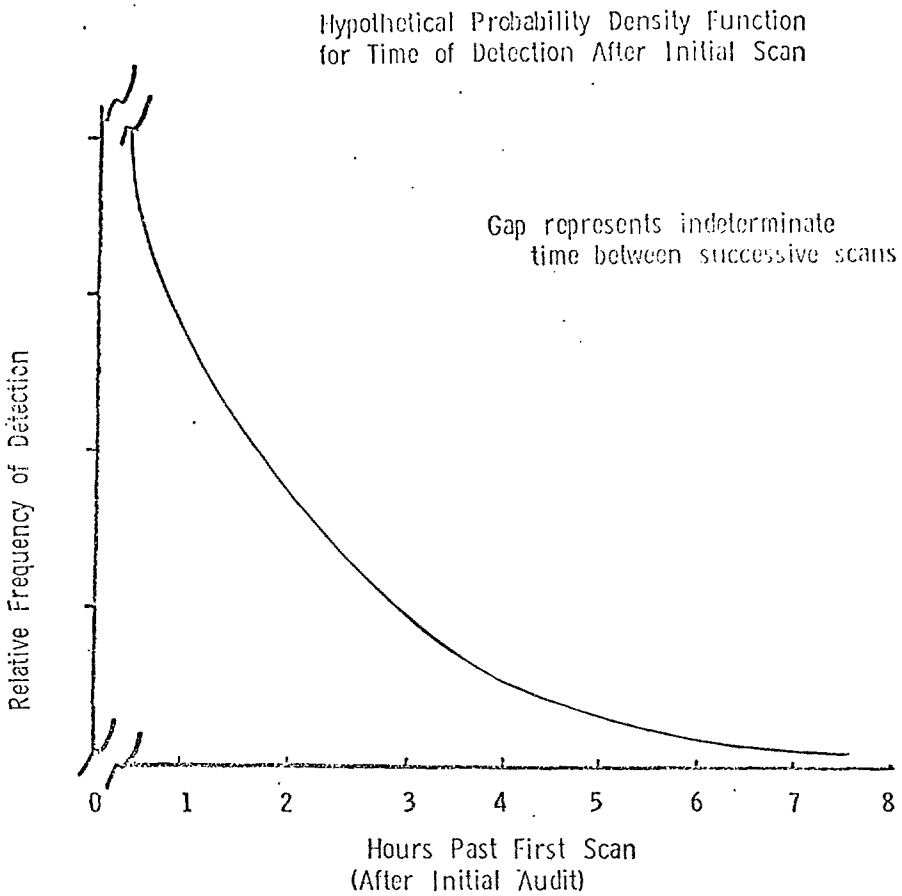
$P(S_{\text{any 1 item}} | \text{correct use}) = .99$

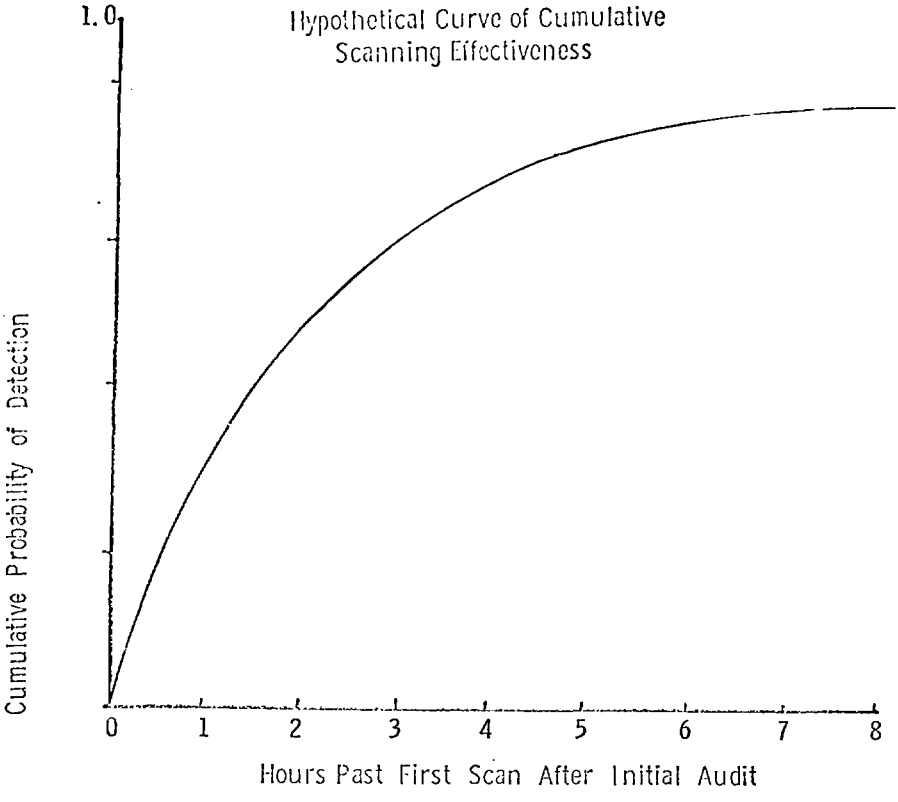
$P(S_{\text{any 1 item}} | \text{improper use}) = .9$

$P(S_{\text{any 1 item}} | \text{1/2 proper \& 1/2 improper use})$

$= .5 \times .99 + .5 \times .9 = .945 \approx .95$

$P(S_{\text{all N items}} | \text{above use}) = .5(.99^N + .9^N)$


Hypothetical Probability Density Function
for Time of Detection After Initial Scan
Gap represents indeterminate
time between successive scans
Relative Frequency of Detection
0
1
2
3
4
5
6
7
8
Hours Past First Scan
(After Initial Audit)


Hypothetical Curve of Cumulative Scanning Effectiveness
1.0
Cumulative Probability of Detection
0
1
2
3
4
5
6
7
8
Hours Past First Scan After Initial Audit