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PROBABILISTIC SIMULATION OF THE HUMAN FACTOR IN STRUCTURAL RELIABILITY

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Many structural failures have occasionally been attributed to human factors in engineering design, analyses, maintenance and fabrication processes. The human factor is intertwined in all engineering activities to develop durable, safe and reliable products. Every facet of engineering process (planning, designing, manufacturing, inspection, maintenance, communication and coordination between different engineering disciplines) is heavily governed by human factors and the degree of uncertainty associated with them. Factors such as societal, physical, professional, psychological and many others introduce uncertainties that significantly influence the reliability of human performance. Quantifying human factors and associated uncertainties in structural reliability require (i) identification of the fundamental factors that influence human performance and (ii) models to describe the interaction of these factors.

For the purpose of an initial simulation, the fundamental factors assumed to affect human performance are: (i) health, (ii) home life, (iii) marital status, (iv) work load, (v) job satisfaction, (vi) professional status. It is ludicrous to presume that these are the only factors that influence human performance; however, they constitute a reasonable initial set. Since, these factors have tremendous variability on a timely basis, human performance also inherits the uncertainty associated with this variability. Therefore, it is more appropriate to simulate human performance from a probabilistic standpoint. Many researchers describe uncertainties of fundamental (primitive) factors in many different ways such as probability density function, stochastic process, fuzzy set approach, etc. Generally, these models are based on subjective information and description. An approach is being developed at Lewis to quantify the uncertainties associated with the human performance. This approach consist of a multi factor model in conjunction with direct Monte-Carlo simulation.

The objective of this presentation is to briefly describe the approach, present some initial results and interpret their implications. The Multi Factor Interaction Model (MFIM) similar to the one for material degradation developed by Boyce and Chamis is adopted to simulate human factor uncertainty. MFIM is based on the concepts of ultimate(maximum), current and reference level of each primitive factor effect. The contribution of a particular factor on the overall human performance is governed by the exponent assigned to it. The magnitude of an exponent can be determined by synthesizing any available data or [redacted] subjective expert opinion. MFIM for human performance, HP can be described mathematically as:

$$HP = \prod_{j=1}^{k} \left(\frac{HF_{u_j} - HF_j}{HF_{u_j} - HF_{o_j}} \right)^{p_j}$$

where

HF_{uj}, HF_j and HF_{oj} are ultimate, current and reference values of human performance due to an individual primitive factor j respectively.
p_j - Exponent corresponding to primitive factor j
k - total number of effects.

The approach developed herein models each term of the human factor uncertainty in the form of a probability density function and couples MFIM with the Monte-Carlo simulation to obtain cumulative distribution function of human performance. The effect of the exponent magnitude in the MFIM is evaluated by using different values and range of the exponents. The statistical distributions of exponents for each case of simulation is selected randomly from a desired range. The variation of human performance due to different range of exponent magnitude at different probability levels are plotted in the form of a bar chart. The cumulative distribution functions (CDF) of human performance are also plotted. Since, the quantification is in the form of CDFs, it is easy to incorporate it in the reliability algorithms.

Further work on probabilistic simulation of human performance is under progress. The research in several areas such as incorporating into the probabilistic structural analysis and risk assessment is under progress. The current paper describes the primary objectives, problems, analytical models and simulation techniques relevant to the prediction of human performance and its impact on structural reliability.

References:

1. Boyce,L. and Chamis C.C., "Probabilistic Lifetime Strength of Aerospace Materials Via Computational Simulation", 31st Structures, Structural Dynamics and Materials Conference, Long Beach, CA April 1990.

PRESENTATION OUTLINE:

- o BACKGROUND
- o OBJECTIVE
- o APPROACH
- o SIMULATION PROCESS
- o RESULTS
- o CONCLUDING REMARKS
- o FUTURE EFFORT

BACKGROUND:

o ATTRIBUTES TO ENGINEERING FAILURES

- MANUFACTURING
- MATERIAL
- OPERATION
- MAINTENANCE
- INSPECTION
- HUMAN FACTOR

o UNCERTAINTIES ASSOCIATED WITH HUMAN FACTOR PLAYS SIGNIFICANT ROLE IN ENGINEERING ACTIVITY

OBJECTIVE:

DEVELOP A METHODOLOGY TO SIMULATE HUMAN FACTOR UNCERTAINTY AND QUANTIFY THE HUMAN PERFORMANCE PROBABILISTICALLY

APPROACH:

- o **FUNDAMENTAL HUMAN FACTORS AFFECTING HUMAN PERFORMANCE**
    - PROFESSIONAL STATUS
    - HOME LIFE
    - JOB SATISFACTION
    - HEALTH
    - MARITAL STATUS
    - WORK LOAD

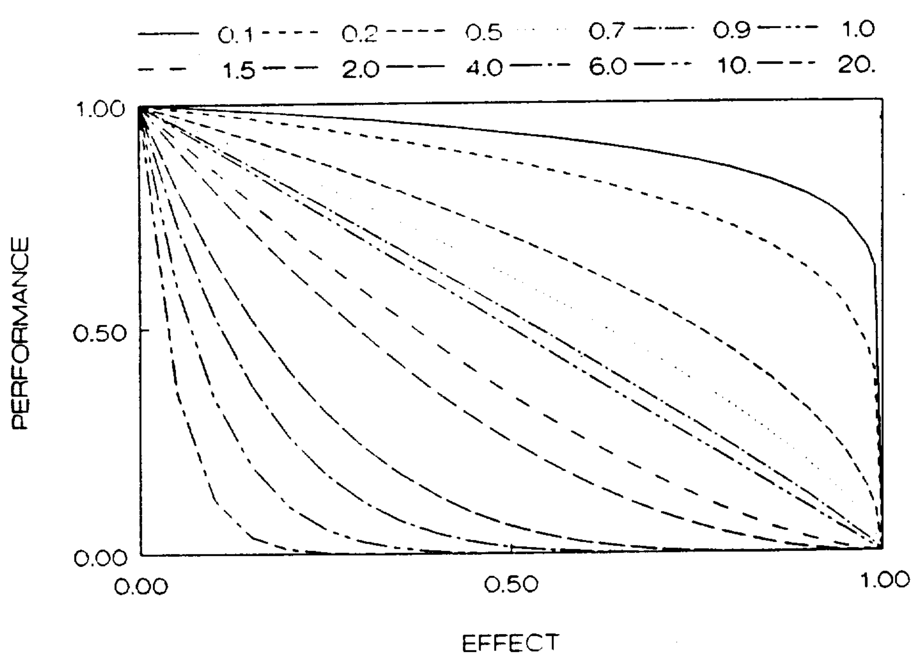
- o **HUMAN PERFORMANCE, P IS EVALUATED BY USING MULTI-FACTOR INTERACTION MODEL FOR HUMAN FACTORS, HF:**

$$P = \prod_{j=1}^{k} \left(\frac{HF_{F_j} - HF_j}{HF_{F_j} - HF_{o_j}} \right)^{p_j}$$

- o **HF_j and p_j ARE CONSIDERED TO BE RANDOM AND NORMALLY DISTRIBUTED**

- o **MONTE-CARLO SIMULATION IS USED FOR PROBABILISTIC ANALYSIS**

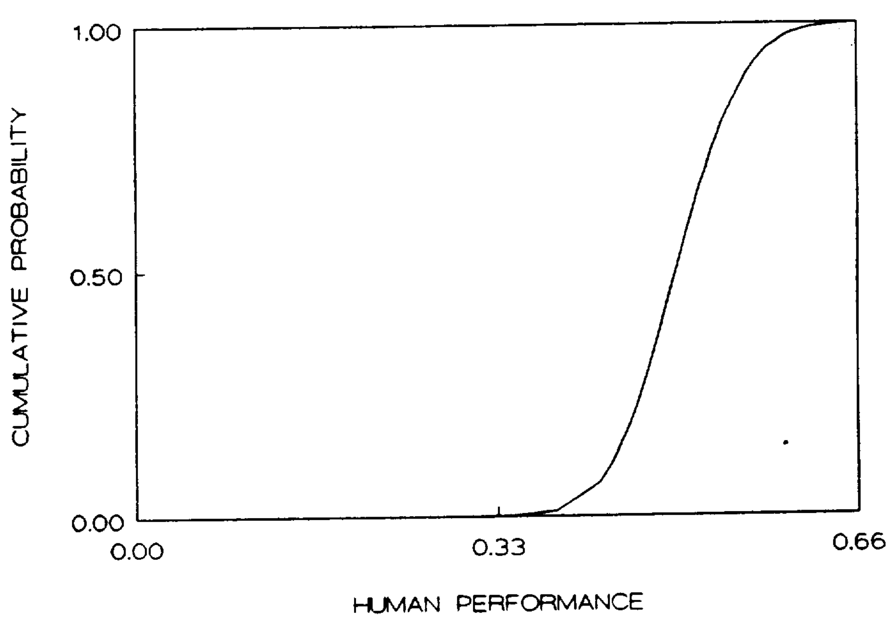
EFFECT OF VARIATION IN EXPONENT



FUNDAMENTAL HUMAN FACTOR DISTRIBUTIONS: EXPONENT BETWEEN RANGE (0-1)

Primitive Variable		Mean	Coefficient of Variation (%)
Professional Status	Final	1.0	0.0
	Current	0.30	33.3
	Exponent	0.267	10.0
Home Life	Final	1.00	0.0
	Current	0.25	20.0
	Exponent	0.013	10.0
Job Satisfaction	Final	1.00	0.0
	Current	0.40	25.0
	Exponent	0.176	10.0
Health	Final	1.0	0.0
	Current	0.2	20.0
	Exponent	0.964	10.0
Marital Satisfaction	Final	1.0	0.0
	Current	0.30	26.7
	Exponent	0.252	10.0
Work Load	Final	1.0	0.0
	Current	0.35	22.9
	Exponent	0.466	10.0

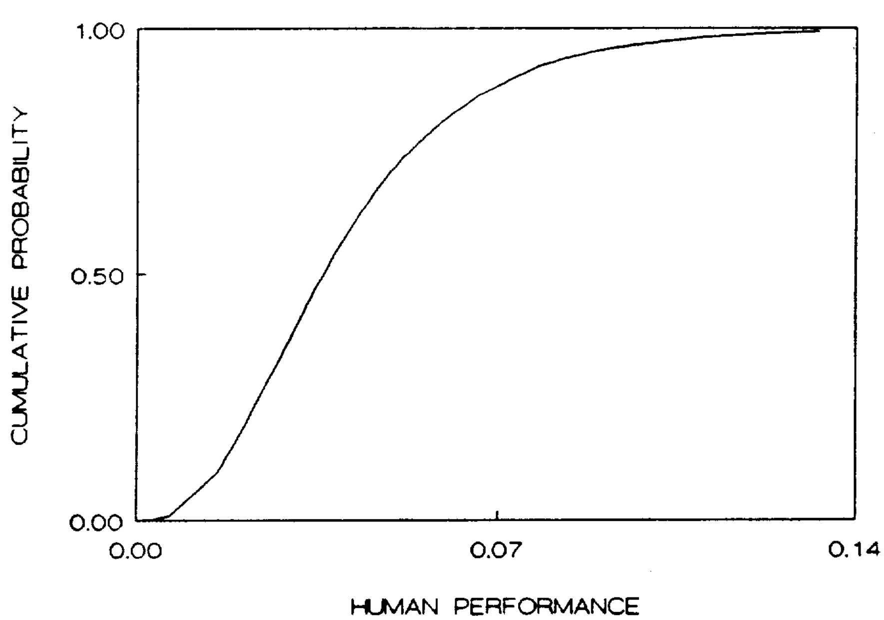
CDF OF HUMAN PERFORMANCE RANDOM EXPONENTS BETWEEN (0-1)



FUNDAMENTAL HUMAN FACTOR DISTRIBUTIONS:
EXPONENT BETWEEN RANGE (0-3)

Primitive Variable		Mean	Coefficient of Variation (%)
Professional Status	Final	1.0	0.0
	Current	0.30	33.3
	Exponent	1.85	10.0
Home Life	Final	1.00	0.0
	Current	0.25	20.0
	Exponent	1.691	10.0
Job Satisfaction	Final	1.00	0.0
	Current	0.40	25.0
	Exponent	2.703	10.0
Health	Final	1.0	0.0
	Current	0.2	20.0
	Exponent	0.099	10.0
Marital Satisfaction	Final	1.0	0.0
	Current	0.30	26.7
	Exponent	0.852	10.0
Work Load	Final	1.0	0.0
	Current	0.35	22.9
	Exponent	1.005	10.0

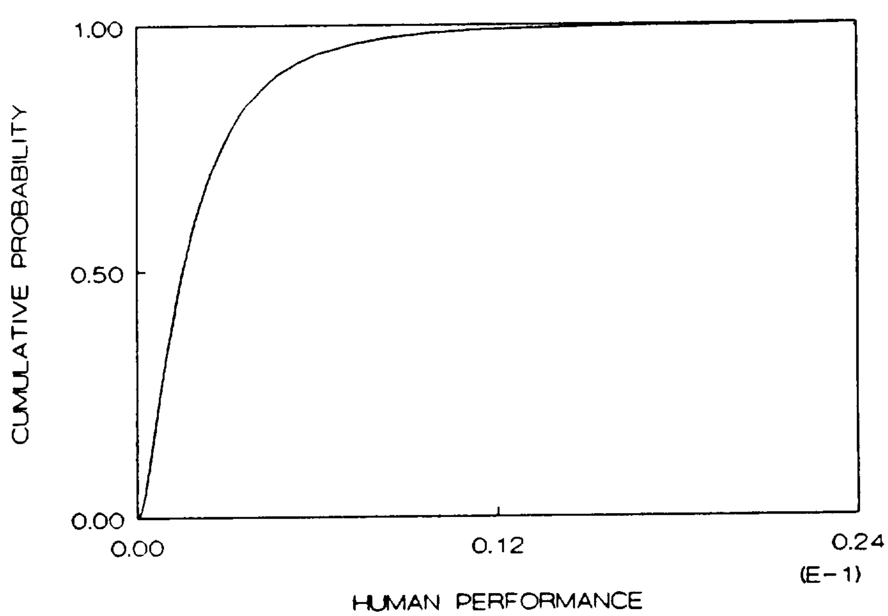
CDF OF HUMAN PERFORMANCE
RANDOM EXPONENTS BETWEEN (0-3)



**FUNDAMENTAL HUMAN FACTOR DISTRIBUTIONS:
EXPONENT BETWEEN RANGE (0-5)**

Primitive Variable		Mean	Coefficient of Variation (%)
Professional Status	Final	1.0	0.0
	Current	0.30	33.3
	Exponent	4.007	10.0
Home Life	Final	1.00	0.0
	Current	0.25	20.0
	Exponent	1.923	10.0
Job Satisfaction	Final	1.00	0.0
	Current	0.40	25.0
	Exponent	1.926	10.0
Health	Final	1.0	0.0
	Current	0.2	20.0
	Exponent	3.912	10.0
Marital Satisfaction	Final	1.0	0.0
	Current	0.30	26.7
	Exponent	2.897	10.0
Work Load	Final	1.0	0.0
	Current	0.35	22.9
	Exponent	3.597	10.0

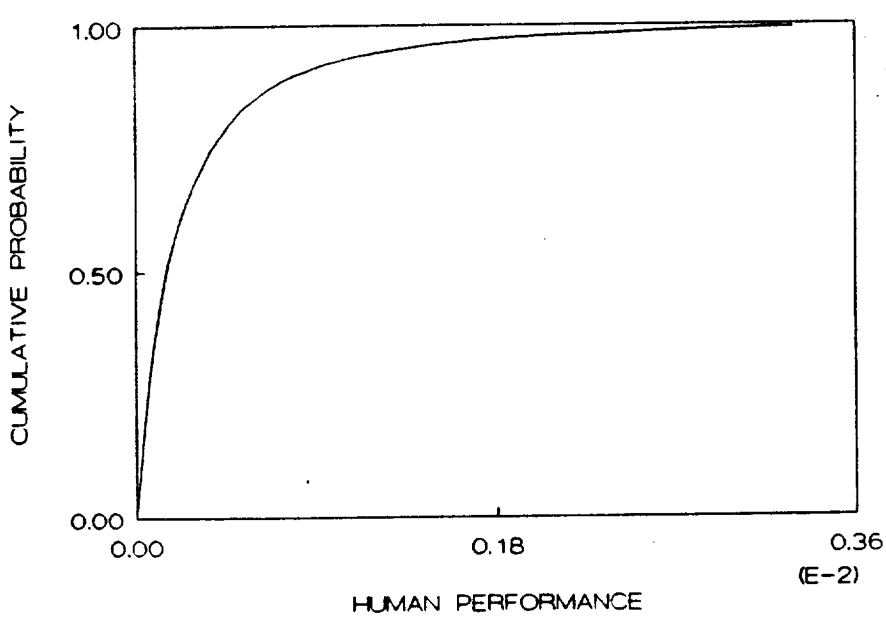
**CDF OF HUMAN PERFORMANCE
RANDOM EXPONENTS BETWEEN (0-5)**

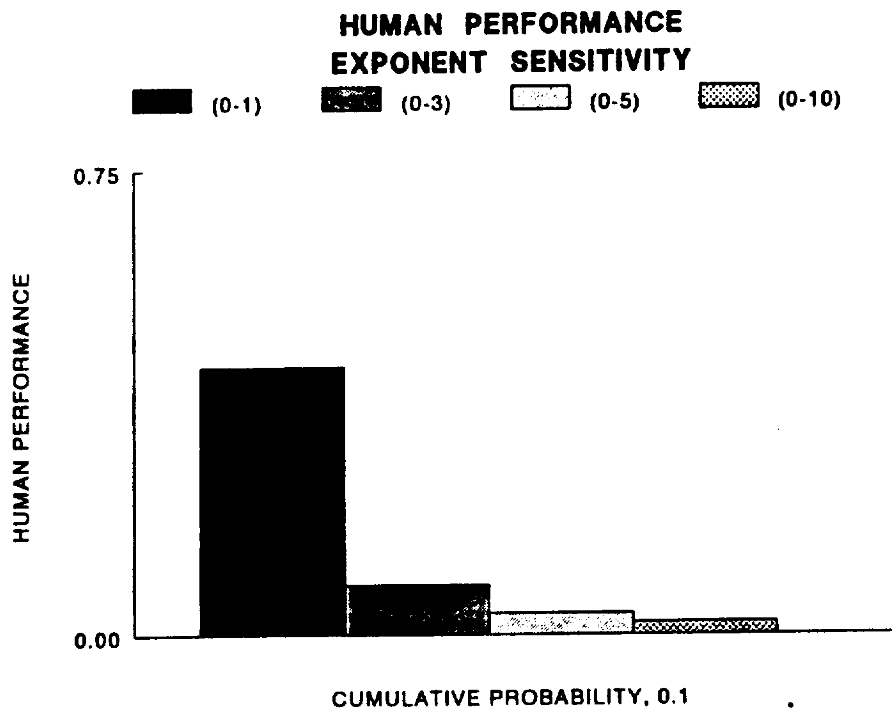


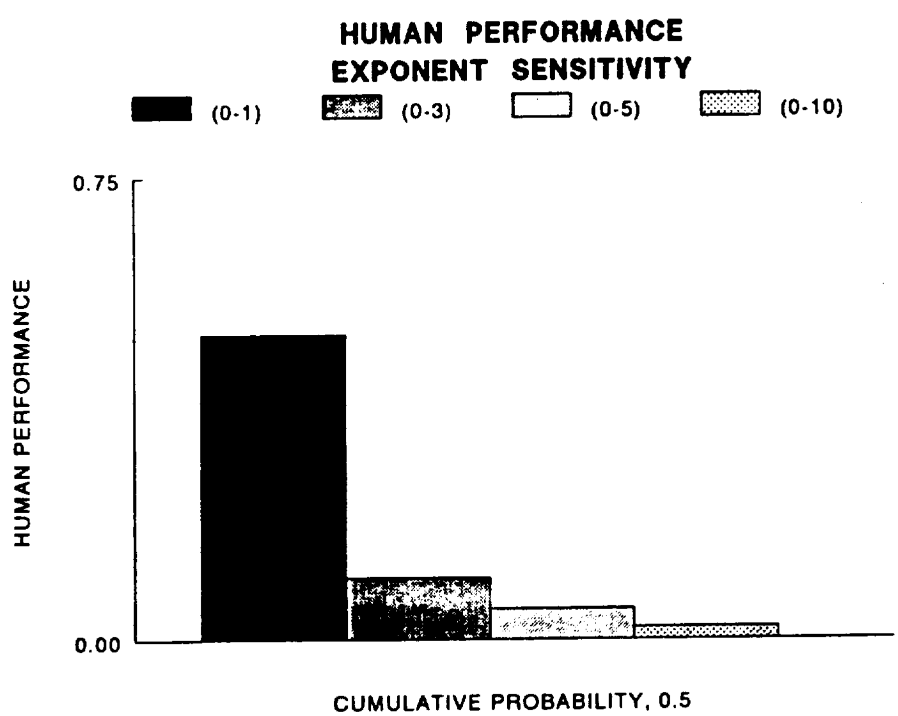
**FUNDAMENTAL HUMAN FACTOR DISTRIBUTIONS:
EXPONENT BETWEEN RANGE (0-10)**

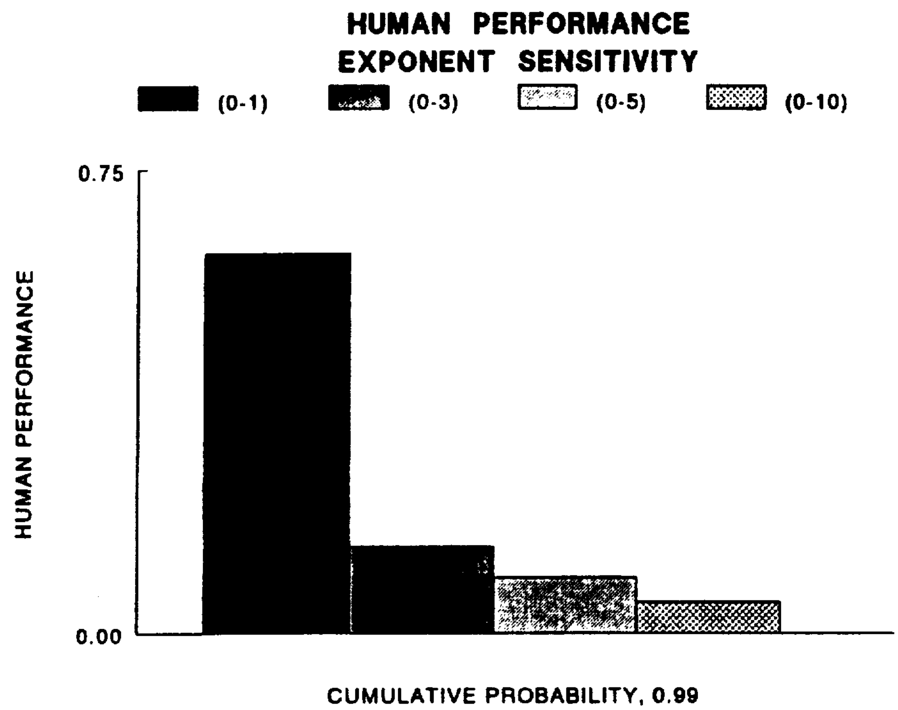
Primitive Variable		Mean	Coefficient of Variation (%)
Professional Status	Final	1.0	0.0
	Current	0.30	33.3
	Exponent	5.431	10.0
Home Life	Final	1.00	0.0
	Current	0.25	20.0
	Exponent	6.903	10.0
Job Satisfaction	Final	1.00	0.0
	Current	0.40	25.0
	Exponent	0.518	10.0
Health	Final	1.0	0.0
	Current	0.2	20.0
	Exponent	1.737	10.0
Marital Satisfaction	Final	1.0	0.0
	Current	0.30	26.7
	Exponent	3.301	10.0
Work Load	Final	1.0	0.0
	Current	0.35	22.9
	Exponent	6.826	10.0

**CDF OF HUMAN PERFORMANCE
RANDOM EXPONENTS BETWEEN (0-10)**




HUMAN PERFORMANCE
EXPONENT SENSITIVITY
(0-1)
(0-3)
(0-5)
(0-10)
0.75
0.00
HUMAN PERFORMANCE
CUMULATIVE PROBABILITY, 0.1


HUMAN PERFORMANCE
EXPONENT SENSITIVITY
(0-1)
(0-3)
(0-5)
(0-10)
0.75
0.00
HUMAN PERFORMANCE
CUMULATIVE PROBABILITY, 0.5



CONCLUSION:

- o METHODOLOGY TO QUANTIFY HUMAN PERFORMANCE UNCERTAINTY IS INTIATED
- o MULTI-FACTOR INTERACTION MODEL CAN BE USED TO SIMULATE HUMAN FACTOR UNCERTAINTIES
- o METHODOLOGY DEVELOPED IS CONSISTENT WITH RELIABILITY ALGORITHM DEVELOPED AT LEWIS RESEARCH CENTER

FUTURE EFFORT:

- o EXTENSION OF THE MULTI-FACTOR INTERACTION MODEL TO INCLUDE ADDITIONAL FACTORS THAT INFLUENCE HUMAN PERFORMANCE
- o INCORPORATION OF THE HUMAN FACTOR UNCERTAINTIES INTO PROBABILISTIC STRUCTURAL ANALYSIS AND RISK ASSESSMENT