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FINAL REPORT

NASA: Model Development for Human Factors Interfacing

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ABSTRACT

The results of an intensive literature review in the general topics of human error analysis, stress and job performance, and accident and safety analysis revealed no usable techniques or approaches for analyzing human error in ground or space operations tasks. A Task Review Model is described and proposed to be developed in order to reduce the degree of labor intensiveness in ground and space operations tasks. An extensive number of annotated references are provided.

FOREWORD

This grant (NAG10-0010) was directed by The Future Projects Office at Kennedy Space Center, Florida.

This report summarizes the results of Phase I. There are anticipated to be three successive Phases. Developed and validated will be two models for addressing the potential for human error in ground or space operations tasks. First will be The Task Review Model (TRM) which will reduce the degree of labor intensiveness in a task. Second a Human Role Evaluation Model (HREM) will determine a Role Criticality Criterion (RCC) for each human role in a task which has been reviewed by the TRM. There will be different levels of criticality in the RCC. In addition, for human roles with undesirable RCC values, the HREM will develop a Personnel Management Criterion (PMC) which will delineate skill-level and experience required and recommend work period, break period, and rest period durations.

ABSTRACT

The results of an intensive literature review in the general topics of human error analysis, stress and job performance, and accident and safety analysis revealed no usable techniques or approaches for analyzing human error in ground or space operations tasks. A Task Review Model is described and proposed to be developed in order to reduce the degree of labor intensiveness in ground and space operations tasks. An extensive number of annotated references are provided.

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CHAPTER I

FINAL REPORT

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NASA: Model Development for Human Factors Interfacing

Grant NAG 10-0010

Space systems operations comprise a broad spectrum of different activities. There are multiple checks of electrical, mechanical, and fluid connections; fuel and oxidizer transfers; onloading, activating/deactivating payloads/experiments; orbiter and space vehicle relocations, etc. A large portion of these operations are labor intensive in that many humans, many manual tasks, or a combination of both are involved. Many of these tasks are also hazardous toward personnel, systems, and missions due to the space environment and/or hazardous systems involvement. Due to the complexity of space operations, the involvement of hazardous systems, and the high degree of labor intensiveness, most space operations require long periods of time to accomplish. It is noteworthy that the time required for a human to successfully accomplish any task increases in direct proportion to the complexity of the task. It is anticipated that operations activities will be a primary limiting factor in determining future flight rates as well as the rate at which space experiments and activities can take place and that human errors could contribute significantly to a degradation of operational success. Therefore, methods to evaluate human involvement and to analyze the human role are necessary to ameliorate the potential for controlling critical errors.

Let the premise therefore be that there exists a potential for human error (hereinafter referred to as HEP: Human Error Potential) and that there are a large number of human errors which are deemed undesirable in ground and space systems due to the character, magnitude, severity, and/or timeliness of the consequences of such errors.

In order to address these two major issues of this premise, it is desirable to first quantify the HEP so as to be able to predict the likelihood of error commission in a given application. The ability to so predict would enable analysts to generally characterize the likelihood of severe consequences to possible human errors.

Secondly, it is desirable to delve into the causal factors which contribute (or induce) humans to commit errors. Clearly, if it is known what makes humans err, then it is presumed possible to modify the situation in some manner or form to reduce the HEP.

Therefore, the approach can be summarized as first being able to predict the HEP and second attempting to reduce this potential. It is fundamental that being able to predict HEP must come before being able to reduce it because if the potential cannot be reliably quantified, it would be difficult at best to characterize the efficacy of any HEP reduction efforts.

Before any attempts are made to address the issues of the premise in this manner, it is advisable to survey the field to ascertain what methods and techniques have already been developed to deal with HEP. The most logical (and usually the most effective) manner in which to survey the practices in use in the

field is to conduct a review of the professional literature. In this instance the professional literature is construed to entail books, journals, dissertations, conference proceedings, published reports in the private sector, and reports in the public sector such as that which is available from the National Technical Information Service (NTIS).

The logic here is that there is no reason to reinvent the wheel, namely, if there is a valid, applicable technique reported in the field it is more effective use of the time to find it via a literature review than it is to develop a new technique from scratch.

It should be intuitively obvious that regarding the topic of HEP the 'field' is extraordinarily broad in scope simply because human beings are involved in nearly all activities. Therefore it was decided not to select a field of operation, say manufacturing or sports, and investigate what might be reported in literature related to that area. This approach would tend to grow in scope in direct proportion to the time invested and it could possibly overlook usable information available from sources not selected.

Consequently, an extensive review of the literature was conducted in the following manner. The purpose of the review was to determine what has been reported in the literature in the general areas of (a) human error analysis, (b) stress and job performance and (c) accident and safety analysis. Interest in area (a) was predicated on the assumption that effective techniques in dealing with the potential for human error have been developed which are applicable to ground (or space)

operations tasks. Interest in area (b) was predicated on the contingency that tangible results of the first part of the review might not be realized. The rationale was that if no usable techniques in human error analysis are evident in the literature, then perhaps usable techniques in the area of stress and job performance have been developed and reported which could be used as a foundation for the development of a human performance analysis technique which could be used in dealing with HEP. Interest in area (c) was predicated on the idea that usable techniques have been developed through analysis of the periods following the occurrence of a human error.

The human error analysis portion of the literature review was planned to be as broad in scope as possible. Subtopics as classification schemes (taxonomies), error data banks, causes of human error, consequences of human error, and human reliability were investigated.

The stress and job performance portion of the review was planned also to be broad in scope. Included were such subtopics as job stress, stress due to non-job sources, means of measuring (and enhancing) job performance, psychophysical aspects of job performance, and fatigue.

The accident and safety analysis portion of the review concentrated on accident investigations and safety program development and evaluation. The general results of the literature are described in the following paragraphs. More specific information can be found in Appendices A and B. Appendix A contains a cross-sectiona' reference sheet for each of the first two areas of the literature review. These sheets

reflect with respect to area subtopics the type of information found and the type of source which provided the information. Appendix B is a list of annotations of sources which were determined noteworthy. This appendix is broken down into three parts corresponding to the three areas of interest. Appendix D contains the references reviewed. This is a complete reference listing, meaning that the list cites all sources reviewed. Not all of the sources reviewed contained useful information. Those sources which contained the most useful information are specifically discussed in Appendix B.

The results of the review in the area of human error analysis were that in general there were predominantly only contributions made by theorists. There were very few reports made by empiricists and there were virtually no reports made by practitioners in human error analysis. In fact, the paucity of practitioner provided reports is evidence to the conclusion that human error analysis is not an area of practice at all. In addition, it appears that although there may be interest in HEF in the field no one is reporting on any direct application attempts to do anything about it.

There were only a handful of reports made by empiricists in the area of human error analysis and all of these were laboratory studies which addressed the characteristics of different types of human error (e.g., muscular coordination, mental computation, etc.), and consequently were not applications studies. For edification, applications studies are investigations which deal with a specific activity (or task) in its entirety. Such may be

done in the laboratory or the field. The results of such studies are tangible and interpretable for applications to other similar activities. On the other hand, foundation level studies are invariably performed in the laboratory. These studies endeavor to establish a general data base in an area of human activity. The end result (after many studies) is a compendium of data which would provide general design guideline information for a series of related tasks. Therefore the results of individual studies of this type are not usable for applications, although such studies are highly meritorious due to their contributions made to the collective goal.

As yet these foundation studies have not been performed with enough breadth and depth for there to be any useful compendium of design guideline information in the area of HEP.

The reason why there are a low number of instances of reported empirical and practitioner studies is most likely due to the fact that those individuals interested in human error analysis can not identify worthy methods or approaches because the large number of theorists in this area are at odds with each other. A thorough reading of the published material from the theorists engenders a large tendency towards confusion. There appears to be no commonality of purpose and no commonality of approach. One group avers that HEP is pervasive and uncontrollable. There have been successful techniques developed to predict the error rates of humans, however. The most well known technique is The Technique for Human Error Rate Prediction - THERP (Swain, 1973).

In reviewing the sources located in this area a conclusion

or generalization in spite of the tendency towards confusion does surface. This generalization is that human performance activities are not independent. Hence they do not lend themselves to traditional methods of analysis such as statistics (the techniques of which generally call for its events to be independent). In addition, it appears that most theorists agree that human activities are correlated to both the characteristics of the environment and the individual personality. In other words, it is thought that people do not err predictably in similar situations, nor do errors occur predictably person to person in the same situation.

Having ventured these generalizations, it should be recognized that unfortunately insofar as the immediate objective previously posed in the premise is concerned, there is no logical next step. These generalizations, although perhaps interesting and worthy of discussion do not lend themselves to the formulation or development of a solution to the stated problem. In fact, these generalizations are not sufficient guidance to design and conduct an intermediate study the results of which would be intended to address the stated problem. Error rate prediction techniques as mentioned previously could be utilized as evaluators, but short term success can only be expected for reasonably simple (non-complex) and/or unsophisticated systems.

The results of the review of the literature in the areas of stress and job performance and accident and safety analysis are basically similar to that of the first area of interest. In these areas there has been more agreement among the theorists.

But even though this fact would enable there to be a more uniform thrust by empiricists and practitioners such activity has not been reported. The bulk of what was reported has been done by theorists. Generally, the theorists agree that job performance can detrimentally be affected by either an overstress condition or an understress condition. In other words, people do their best work in job situations which are neither an overload (too many tasks, and/or too little time) nor an underload (not enough tasks, and/or too much time). This observation in itself may seem profound enough to lend itself to an application. This however is unfortunately not the case. The problem is that there is no consensus from the theorists (and there have been no reports of empirically based results) which quantitatively delineates how many tasks are too many or too few or how much time is too much or too little. Without this type of quantitative information job design (or redesign) is not a feasible approach to addressing HEP.

The general conclusion, then, based on the thorough review of the literature which has been conducted is that there have not been any techniques or approaches developed to address HEP or to conduct a human error analysis. Furthermore, since the sources reviewed were predominantly theoretical discourses, there are not enough tangible data to use to build or design a set of techniques or approaches to deal with HEP or to conduct human error analyses.

It would appear then that the objective of this study as has been stated previously in the premise cannot be supported by the results of the literature review. This is not the case. The

fact that nothing has been done before in the empirical or practitioner communities (and reported in the literature) is not a preventative from doing anything original. The only reservation might be that an original approach has a certain degree of risk associated with it in that without documented support there is no assurance of success.

There are two general approaches which can be addressed at this juncture on an original approach. The first is to design a means of analyzing and quantifying (or predicting) HEP in some manner which will have usability with and application to typical ground (or space) operations tasks. This would be a foundation level type study. The second approach is to postpone any formal dealings with HEP and endeavor to reduce HEP in an informal or indirect manner. In other words, rather than confront HEP in ground operations tasks as a reality and try out heuristic innovations to deal with it, it might be more effective to initially try to deal with the major reason why HEP exists in the first place, namely the human being. If it were possible to reduce the number of human beings involved in a ground (or space) operations task, it is logical that the HEP associated with that task would go down. Recognize that it is not known how much the HEP would go down because it is not yet known how to reliably quantify HEP. But if this hypothesis that HEP is directly (or positively) correlated to the number of people (or more aptly, the degree of labor intensiveness) on a given task, is deemed valid, then it is recommended to adopt the second approach as the means of initially dealing with HEP at Kennedy Space Center.

Thus it is recommended that this project involve the development and validation of two Human Factors Models: The Task Review Model (TRM) and the Human Role Evaluation Model (HREM). The TRM is a means of analyzing a ground (or space) operations task. It will isolate the task's key objectives and functions and will perform a functional allocation process for each task in the interest of reducing the degree of labor intensiveness of the task. After space operations tasks have been reduced in labor intensiveness using the TRM, the HREM will be applied to those tasks identified through the use of the TRM as still labor intensive. The HREM will consist of two techniques, the Role Criticality Criterion (RCC) and the Personnel Management Criterion (PMC). The RCC will be a means of evaluating human roles to ascertain the severity of the possible consequences due to human errors. The RCC will assign a numerical quantity to the analyzed tasks and will be designed to be parallel to the criticality numerical quantity factors assigned in the standard NASA system hardware failure analysis schemes. After the RCC has been applied to tasks to determine their criticality, the PMC can then be applied to those tasks having an undesirable RCC. The PMC will be a specification of the skill level and experience required of humans to accomplish the specific task being analyzed and will delineate minimum/maximum (as appropriate) work period, break period, and rest period durations. The TRM will be developed and validated in Phase II and is described in detail as follows. Once a ground or space operations system has been reviewed by the TRM and HREM the next logical steps are one, to utilize an error rate prediction technique (e.g., THERP, referred

to previously) to identify specific human actions which warrant further scrutiny, and two to delve into the psychophysical aspects of these identified actions.

Task Review Model

The purpose of the Task Review Model (TRM) is to objectively minimize the degree of labor intensiveness in a ground or space operations task. A minimization in the degree of labor intensiveness is interpreted to include either a reduction in the number of humans involved in the task, a reduction in the instances of manual operations in the task, or both of these reductions on an optimization basis within the limitations of current automation technology.

The TRM will be designed to be applied to any type of task in a manner which is independent of how the task is currently being conducted. This is anticipated to be accomplished by compiling information from such individuals as the task designer and the task supervisor rather than observing the actual execution of the task.

The anticipated results of a task reviewed by the TRM will be two-fold. First, the TRM will provide an objective description of what activities must be accomplished in order for the reviewed task to be accomplished. The result will be a description in the form of a tree diagram or an organizational chart. This task description will be streamlined and as parsimonious in the number of activities as possible. Hence such a description would form an ideal foundation for a contract bid proposal solicitation. Secondly, there will be an assignment made for each listed activity. The assignment will either be 'human' or 'non-human.' The human assigned activities are those

which will be reviewed by the Human Role Evaluation Model (HREM) to be developed in Phases III and IV of this project. Similarly this activity assignment facet of the TRM results will provide qualified guidance to prospective contractors in how to prepare their bids. This requirement shall be realized as a benefit due to the fact that each prospective vendor will bid on the same conception of the task -- not on each individual interpretation of how the task can be executed.

Generally, the TRM is an analysis approach which endeavors to include only those activities which are necessary to satisfy the stated goal. Let this stated goal be called the Objective of the task. The definition which the Objective satisfies is: What is the task supposed to do? or Why is the task necessary? Therefore the first step of the TRM is to determine the Objective of the task. There must be a single simply stated Objective for each task. If a selected task cannot be described by a single Objective then it will be deemed a higher-order task and, as such, warrant a number of separate applications of the TRM. Therefore an additional benefit of the TRM technique is to identify all the basic (zero-order) tasks which comprise a single ground (or space) operations system (where 'system' is used to be synonymous with a higher-order task).

For qualified basic tasks, the next step in the TRM is to identify, and label all those activities which are necessary to achieve the stated Objective. Allow for these activities now to be called Functions. The determination of those Functions which satisfy the stated Objective is the most involved portion of the

TRM. Not only must this portion ensure that there are enough Functions specified to fully support the stated Objective, but the descriptions of the Functions must be explicit enough for the TRM to make the human and non-human assignments to the Function in the next step.

The next step in the TRM determines whether a human can or can not accomplish each listed Function of the task. Ordinarily, the Functional Allocation step makes this determination on the basis of how the human resources can best be utilized. In the design of the TRM for this application, the Functional Allocation determination will be made on the basis of how available non-human resources and technology can best be utilized, because, as stated previously, the primary purpose of this TRM is to minimize the degree of labor intensiveness in ground (or space) operations tasks. An illustrated example is provided in Appendix C.

Because the primary product of this project is a reduction in the potential for human error in ground (or space) operations tasks, the Functional Allocation step of the TRM will not provide specific descriptions of the character of the non-human allocations. Let it remain for subsequent projects to address this issue. As a departure point for prospective projects in this vein, the final deliverable of the TRM in Phase IV will include a detailed description of the logic applied in the Functional Allocation step which accomplishes the determination of whether the allocation is to be human or non-human.

It is noteworthy at this juncture to identify that the Functional Allocation step will be designed to make a human

allocation primarily by default. That is, a human allocation will be made only if a non-human allocation cannot be supported by the Functional Allocation logic. This is because the primary purpose of the TRM is to minimize the degree of labor intensiveness in the targeted tasks.

The exact manner in which the TRM will be applied is as yet to be determined, but will most likely be of a computer software type. It is planned for the TRM to be fully interactive and for it to consolidate data gleaned from more than one source. Further, it is considered highly desirable for the final TRM deliverable to operate in real-time and be as easy to operate and apply as possible. The attainment of these characteristics will be given the highest of priorities in the design, prototype, and validation phases of the TRM development.

APPENDIX A

CROSS-SECTIONAL REFERENCE SHEETS

Included in this appendix are three cross-sectional reference sheets one each for the literature review areas of human error analysis, stress and job performance, and accidents and safety.

These sheets reflect the general types of activity considered by the references (SUBJECTS) and the general type of source of the references (SOURCES).

APPENDIX A: CROSS-SECTIONAL REFERENCE SHEETS

	SUBJECTS							SOURCES					
	AIRCRAFT	MOTOR VEHICLES	INDUSTRY	NUCLEAR	THEORY or BASIC RESEARCH	MILITARY	DISSEMINATIONS	GOVERNMENT DOCUMENTS	CONFERENCE PROCEEDINGS	BOOKS	PERIODICALS	UNPUBLISHED ARTICLES	MILITARY
CLASSIFICATION SCHEMES			3		14		1	1	1	6	7	1	
DATA BANKS			1		2	1		1		1	2		
INCLUDING HE w/ M/C ERROR					1	2				3			2
DETERMINING SIGNIFICANCE of HE or CAUSES of HE	1		3	1	11	1	1		1	7	8		1
QT			4	2	17	1	1	1	9	3	7	1	3

APPENDIX A: CROSS-SECTIONAL REFERENCE SHEETS

	AIRCRAFT	NUCLEAR POWER	MILITARY	MEDICAL	INDUSTRY	MOTOR VEHICLES	POLICE	EDUCATION	INFORMATION PROCESSING	OTHER	BOOKS	PERIODICALS	GOVERNMENT DOCUMENTS	CONFERENCES PROCEEDINGS	DISSERTATIONS
GENERAL STRESS	11	1	2	3	10		1	3	1	20	15	20	16		1
OCCUPATIONAL STRESS			1		8						8	1			
HUMAN PERFORMANCE	12	1	12	8	21	1	2	4	2	10	15	35	8	10	7
SAFETY MANAGEMENT					2						2				
HUMAN RELIABILITY	2		1		1								2	2	
OCCUPATIONAL HEALTH	1				5					3	8	1			
	SUBJECTS										SOURCES				

APPENDIX A: CROSS-SECTIONAL REFERENCE SHEETS

	SUBJECTS													SOURCES				
	AIRCRAFT	MOTOR VEHICLES	HUMAN (SELF)	HOME	INDUSTRY	NUCLEAR POWER	FARM	FIRE/EXPLOSION	BOATS	UNDER WATER	RAILROAD	THEORETICAL	OTHER	BOOKS	PERIODICALS	GOVERNMENT DOCUMENTS	CONFERENCE PROCEEDINGS	DISSERTATIONS
STRESS	6	14			3	2			3			1		29				
SAFETY	1	3	1	1	4	1	1					1		13				
RISK		6		2								2		10				
ACCIDENT	8	35	2	4	14	2	1	1	1	1	1	5	2	63	3	2		
HUMAN ERROR	3				2									5				
MACHINE DESIGN					2									2				
UNSAFE ACTS					1									1				

APPENDIX B

ANNOTATED REFERENCES

The annotations are by alphabetical order according to author for easy reference and each paragraph gives information provided by one author.

PART I: Human Error Analysis

Adams (1982)

Feels that error is probabilistic and could be simulated using Monte Carlo techniques. Human error should be included with equipment analysis in determining the reliability of systems. Feels, however, this would be impossible. Feels that to be able to analyze error fundamental units of behavior whose success or failure would be used in the calculations must be established. These would be irreducible stimulus-response categories. States that humans are a closed loop system. They can detect and correct their own errors. Expresses a common belief that error is multidimensional. A response can be omitted, performed out of sequence, transferred from another sequence, wrongly timed, or applied with inappropriate force. Has a current belief that human sequences of action are not independent therefore can not be calculated like machines. Bases a lot of his work on Swain.

Aitken (1982)

Feels that if faults are slow in developing, the system can alert humans to take corrective action, otherwise automatic controls are necessary. Factors which affect human response to an error conditions are: 1. the process which is being controlled, 2. knowledge of the status of the system, 3. prior knowledge of the effects of the control action, 4. human factors specifically relating to the operator and 5. training.

Altman (1964, 1967)

Tries to find a similarity among errors so one can 1. search for significant error 2. identify alternative ways to reduce error or its consequences, and 3. evaluate alternative solutions to error problems. Feels error classification schemes fall into three categories: 1. performance orientation (what a person is, or is supposed to be doing when an error occurs), 2. situational orientation, and 3. individual orientation (characteristics of the person). Associates psychological behavior levels and learning categories (e.g., sensing, tracking, and problem solving) with error behaviors. Attempts to link the basic research of psychology with error. Approaches the area of errors at a higher level -- managerial or technical. Feels errors should be indexed to the kinds and conditions of input and output devices or classified by skill and knowledge content. Goes along with situational causation of error. Constructs a block that relates consequences, revocability, and detectability to measure error tendency. Feels that in some cases the individual characteristics of the worker may be used to classify errors. In general each error possible situation has a best way of classification: performance, situational, or individual.

Askren and Regulinski (1969, 1971)

Feel that repetitive tasks can be modeled. State that human error research has fallen into the following categories: developing human error classification schemes, determining the significance of errors to system operations, establishing human error data banks, and devising models and methods for describing and including human error data in system reliability analyses.

Define the following equation to describe reliability:

$$R(t) = e^{-\int_0^t [e(t)dt]}$$

where $e(t)$ = error rate

This equation is supported with a very simplistic derivation and the knowledge that error distributions generally fit well with Weibull, gamma and log-normal distributions. Feel that this applies to continuous operation tasks such as vigilance, monitoring, and tracking.

Beek, Haynam and Markisohn (1967)

The authors were tasked by the Navy to research the Navy's human reliability statistics and suggest improvements. Thus, this study is specific to the Navy in operation and maintenance procedures. The procedure that will be described here was reviewed by Meister. The systems of error reporting used by the Navy were reviewed and critiqued. The authors describe in detail the intricacies of the two models mentioned below. This study did a small literature search. Most previous studies have substantiated the fact that a significant percentage of system unreliability is caused by human error. Feel it is impossible to get reliable data and it is virtually impossible to test people in a laboratory and use the results for predicting human performance under actual conditions. Even if this were possible the results would not apply to another person. Agree with setting up a data base as the forefront of the research effort on human error. Feel the need to be able to predict human error without depending on human performance data since it is unreliable. Human error predictions should be inferred from existing equipment performance data. Define human error as any action of the human element of a system that is inconsistent with a predetermined behavioral pattern established in the system specifications and in the resulting system design. System failure is subgrouped as total system failure and system degradation failure. Two approaches to quantitative techniques were developed: 1. Elementary Reliability Unit Parameter Technique (ERUPT). This technique groups components of the

system into elementary reliability units (ERUs), the lowest levels at which maintenance is performed. This uses existing equipment reliability data to predict human reliability. 2. Multivariate correlation techniques. These are used to relate personnel characteristics to failures. The problem with error reports is that people are reluctant to file them either because of the risk of self-incrimination or co-worker incrimination since many reports are used for disciplinary or promotion review purposes. Also, some systems give categories to choose from in filling out the report. If too many categories are given only a few actually get used. Refer to Shapero (1960) who said 20 to 54% of all system malfunctions in nine missile systems studied were caused by human error. People arbitrarily blame most problems on lack of training or failure of personnel to follow procedures. Feel a taxonomy is needed before anything else in human reliability research. Feel that human reliability lacks common definitions. Feel that the only errors to be included in reliability analysis are those that affect system performance. Examples of classifications: terminal error, design error, operating error, maintenance error, contributory error, performance of a required action incorrectly, failure to perform the required action, performance of a required action out of sequence, performance of a non-required action, errors of omission (1. errors of memory and 2. errors of attention), and errors of commission (1. errors of identification, 2. errors of interpretation, and 3. errors of operation). This report divides error into two categories: 1. Predictable - established between

the inconsistent behavior and some external influence. This type of error can be reduced by human factors design. 2. Random errors -- usually when this is identified as the cause there is no further investigation. "All system failures and malfunctions (except certain laboratory tests) can eventually be traced back to some form of human error, whether it occurred on the drawing board, in fabrication, in testing, in operation, or in maintenance." To improve error reporting an impartial party should be used to evaluate the failure. The second method of multivariate correlation mentioned earlier correlates average pay grade, average time since educational training, average time to evaluation, and average formal education to human error.

Carnino and Griffon (1982)

Give the following categories of human error 1. operating errors, 2. maintenance errors, 3. testing errors, and, 4. design errors. Support the situational cause of human error theory. Characteristics of the work station which have caused human error may be grouped into eight classes: 1. work organization, 2. design of the work station, 3. time and duration of work, 4. personnel education and training, 5. physical environment, 6. social environment, 7. history of the plant, and 8. individual performances. Give listings of these classifications in detail -- same idea as Performance Shaping Factors (PSF). [See Embrey and Swain] Most frequent causes of human failures are procedures, work organization, and lack of efficient controls. The role of procedures is expanded on since procedures are the interface between man and machine.

Childs (1980)

Discusses parametric tests of significance (on normally distributed scores) especially relative to error-time experiments. States Bradley's optimal-pessimal paradox and then refutes it. This work preceeds Askren (1982) and contradicts it. Bradley's optimal-pessimal paradox is stated as follows: If performance conditions are optimal, then parametric statistical tests tend to be pessimal and vice versa. These are the assumptions: 1. error probabilities are equal across all task segments and fit a Poisson distribution, 2. error commissions uniformly increase task execution times, 3. component error times are orthogonal, 4. robustness of parametric tests is greatly reduced by skewness, and 5. if errors are present there is greater variability in score distributions and hence tend to normalize the distribution. Refutes these assumptions because 1. people simply do not work this way, 2. errors depend on the response stimulus required, and 3. skewness does not matter as long as the distribution is homogeneous in form and variance for various treatments.

Cross (1982)

Looks at the quantitative evaluation area. Uses frequency-consequence diagrams to demonstrate total risk. Event trees show a cause-and-then-effect relationship where fault trees show a effect-and-then-cause relationship. Suggests constructing both to analyze a situation. The event tree can be time oriented and allows for dependencies between systems. The fault tree analyzes the failure of each system independently. These techniques are mainly used to gain a greater understanding of the system under consideration.

Embrey (1976, 1981, 1984)

Looks at Performance Shaping Factors (PSF) and expert judgement to analyze systems and evaluate the probability of failure. Uses the computerized Success Likelihood Index Method (SLIM) in conjunction with a Multi-Attribute Utility Decomposition (MAUD) routine to help reduce bias. In "Application of Human Reliability Assessment (HRA) Techniques to Nuclear Energy Process Plant Design" approaches HRA from a cost effectiveness standpoint. Analyzes effect of design changes on human error. Says that the growing application of computers for routine control functions pushes people to higher control levels which require decision making, diagnosis, trouble shooting, and planning. Different analytical techniques are needed for proceduralized actions and situations where decision making functions predominate. Possible analysis of Proceduralized Situations A. task analysis approach which includes 1. task step 2. inputs, 3. outputs, 4. feedback, 5. error potential, 6. system implications, 7. error recovery, and 8. design implications; B. event trees approach is warranted if task elements are discrete and form an ordered sequential sequence that moves forward in time. Possible analysis of Complex Situations (where thinking is required) A. operator action event tree (OAET) model which define operator actions associated with critical states of a sequence. B. critical decision/action (CDA) operator centered model -- defined in terms of consequences of the decision/action. If a CDA fails it will have a significant effect on safety, and/or production. The CDA model

involves less routine decisions than those analyzed by the OAET model. Has developed a system for analyzing a situation with the CDAs. It is necessary to identify each CDA associated with changes of state. This is based on Rasmussen's model of the interaction of skill-, rule- and knowledge-based behavior. From analysis of error reports characteristic types of error can be associated with each CDA. For each CDA a diagram can be drawn for additional information. Discusses limitations of Technique for Human Error Prediction (THERP) - no sensitivity analysis available and applies only to proceduralized tasks. Has developed a technique to overcome this. C. SLIM - task is evaluated as a whole. It is quantified via the structured application of explicit numerical judgements from groups of experts. (Success Likelihood Index Methodology). This is applied by computers using MAUD. Discusses algorithm using PSFs and expert judgements and SLIs. Since weights are used for each PSF a designer can see where improvements might have the most benefit, therefore the cost effectiveness criteria is satisfied. D. Influence diagram is discussed.

Feggetter (1982)

Uses a checklist based on a systems approach for understanding human error and includes such headings as stress, fatigue, arousal, and personality. Feels we usually find the source of an error but don't really know why it occurred. Feels that it is not possible to categorize errors into unique classes and says that there seldom seems to be a single cause for error. Says there is a combination of cognitive, social, and situational factors which give rise to erroneous actions. These are elaborated on as follows. Cognitive System: acquisition, manipulation, use of information, allocation of attentional resources (overload), emotions, thought processes, past history, and experience. Social: role perception and pressures from other people. Situations: physical environment and stress. Thinks research should be shifted away from memory structures and over to memory processes. Produces a checklist based upon current knowledge of human behavior and the mechanisms and system characteristics which predispose the human operator to error.

Hunns (1982)

Feels that to analytically predict the full set of significant event chains associated with a given human/hardware system is not yet within our capabilities. Human error (or failure) carries connotations of blame and personal deficiency. This is the reason given for some of the inadequacy in error reports procedures. Since people take blame, they tend to not report errors as they should. The majority of human errors are corrected by the person concerned and never become evident to a third party. This goes along with the feedback principle mentioned in other literature. Feels current data approaches are ineffective. "So not only is the human factors data collection activity frustrated by the unyielding nature of the observation environment, but at an even earlier stage the process is confounded because no fundamental basis exists to define the type of information which is really required." This supports those who believe that a taxonomy is needed before human error research can progress. Goes into an elaborate discussion on how a data base should be built with backing from classical probability theory.

Lewis (1981)

Attempts to give a general purpose theory on error. Recognizes that most theoretical approaches are specialized and involve language, math, and the acquisition of perceptual motor skills. An error becomes an error by virtue of its failure to conform with some appropriately chosen standard of correctness. "Under conditions of felt urgency, we make mistakes. And, since error is inherently proliferous, yet more mistakes come piling in on top." Says that errors are self-limiting and people naturally want to rid themselves of them. Desired goals cannot be attained if error gets in the way. Management should not have to convince people to recognize their own erroneous thinking. Feels that of the current literature Swain and Guttman (1980) offer the best classification scheme: omission and commission with the subcategories of commission - extraneous acts, sequential errors, and time errors. Gives definitions of error change according to the situation and what is perceived to be a correct action. Error can occur because a situation was appraised incorrectly, or because inappropriate action was taken. Feels there are two types of error: 1. failure to make a distinction that needs to be made and 2. making of a distinction that does not need to be made (omission - commission dichotomy). Rewords these as 1. errors due to significant omissions and 2. errors due to misdirective inclusions. This was because of the trouble caused by the word "need" above. Says that human error is compounding.

Meister (1964, 1966, 1971, 1973, 1982)

Feels that simulation based methods are more powerful than non-simulation methods and that no general purpose methodology is yet available. Feels strongly there is a great need to develop data banks. Feels that much work needs to be done to solve the problem of task dependency relationships (this refers to those who say that classical probability theory does not apply to human error since there are dependent relationships involved.) Feels that most of the quantitative methods available today are special purpose or require a particular form of input and are still in the developmental stages. Says that the frequency of Human Initiated Failures (HIF), that is failures that result in degradation of performance of the system and reduce equipment, range from 20-80% of all failures reported. States that the distribution of individual operator errors tends to approximate a Gaussian distribution with the mean as constant error and the standard deviation as variable error. Says that operator errors compound linearly. Gives tables of error rates. Thinks we should concentrate on work situation to reduce errors, and that most errors are situation caused. Says a lot about what should be done and has a lot of criticism to hand out. Feels that human error includes causes of error built into the system, i.e. poor human factors design. Classifies error as to cause, effect, and stage of occurrence. Gives two categories of operator error, idiosyncratic (aptitude and motivation) and situational (procedures and training). Types of error are system induced,

design induced, and operator induced. Feels that the casual classifications of error do not imply understanding the error source or the mechanism of the error process. Makes the statement that errors made with discrete tasks are more quickly corrected than those made with continuous tasks. Feels that automation significantly increases the requirements of functional allocation, maintenance, and logistics. Feels that the causes of production error are: lack of training, lack of motivation, inadequate work space, poor layout, poor environmental conditions, inadequate human factors design, inadequate methods of material handling, inadequate procedures, and poor supervision. Says error causation is usually due to multiple factors. Says that errors are caused by a mismatch between the capabilities of the operator (idiosyncratic factors) and the demands of the job (situational factors). There is an error potential in man which is not realized until a predisposing condition, creating a mismatch, permits the error to occur. The predisposing condition is a catalytic agent which translates a potential into an actual error. Feels that nothing is inevitable about error. Errors occur when demands and capabilities do not match. To reduce error mismatching must be reduced. This contradicts a prevailing theory that to err is human and hence errors cannot be avoided. Feels that human variability is not the main cause for system degradation since errors do not build up. Humans are adaptable, and thus are desirable for many tasks. But this adaptability also makes humans one of the causes of error. Says in 1982 that random errors, i.e., those produced by the

inherent variability of people, can be reduced by training and proper selection of personnel. Classifies types of errors as 1. fail to perform required action, 2. performance of unnecessary action, 3. performance of required action at an incorrect time, and 4. making a substandard response. Says 40% of equipment failures are the result of error, and as much as 82% of production defects are caused by human error. Defines idiosyncratic factors to include personal relationships, emotional conflicts, and attitudes. Gives a list of PSFs that predispose a human to error. Feels to evaluate a job a human factors expert should ask questions about each PSF along with: is task within worker's capability, does task cause fatigue or discomfort, is feedback provided, is too much precision required or too many movements, and is the physical environment adequate.

Petersen (1980)

Researches the fields of education, management, psychology and human factors engineering. Looks at basic research as well as applications. Intends for work to be used as a text book. Says an old view is that the prime causative factor in occupational injuries is human error rather than physical conditions. In 1939 Heinrich gave four basic motives for unsafe acts: improper attitude, lack of knowledge or skill, physical unsuitability, and improper environment. Says this view is seen as oversimplified, but this is what most industries use. Heinrich said managers control accident prevention. Says the behavior of people needs to be understood and controlled in order to prevent accidents. Supports the multiple causation theory of human error. Discusses a particular type of fault tree which is management based. Human error results from one or more of three things 1. overload (defined as a mismatch between a person's capacity and the load placed on him in a state), 2. a decision to err, and 3. traps that are left for the worker in the workplace (i.e., poor human factors design). Under the first category falls overload in the forms of physical, physiological, and psychological. Capacity is due to a combination of physical, physiological and psychological endowments, current physical condition, current state of mind, current level of knowledge, skill, temporary reduced capacity due to drugs, alcohol, pressure, and/or fatigue. Load is due to a combination of the quantity of information processing, environment, worry, stress, current state due to personal life,

and/or hazards faced continuously. State is due to the level of motivation, attitude, arousal, and/or biorythmic state. The second category deals with peer pressure, pressure for production quotas, accident proneness, and the instance of risk taking because it is inappropriately considered unlikely for a mishap to occur at the time of the taken risk. The third category deals with incompatibility between the human and the workplace. Human factors applications are generally used to correct this. Quotes Chapanis that humans commit errors because it is logical that they do so in the situation they are in. Says human errors are caused; they do not just happen. Situations cause error and the greatest gain in controlling human error can be made by altering the situation. Says that improvements from redesign of equipment are greater than that from selection of or training of personnel. It is easier to change equipment than people. Design characteristics which increase the probability of error commission include violations of operator expectations, mismatch of abilities and demands, induced fatigue causing circumstances, inadequate facilities or information, and difficult, unpleasant, or dangerous tasks. Says risk taking occurs because judgement of risk is not directly related to the hazard as measured by the worker's performance skills. Skilled workers take less risk than unskilled; younger persons take more risks of a more severe nature than older persons; females take less risks than males. A risk taker is a person with a high anxiety level, high sociability, and low emotional stability. No strong relation between vision acuity and accident repeaters was found. High or low arousal levels cause errors. Thinks an optimal arousal

state for peak efficiency is needed. In discussing accident proneness, says that accident frequency is unrelated to intelligence when such is adequate for the situation. Individuals whose level of muscular reaction is above their levels of perception, are prone to more frequent and more severe accidents than those individuals whose level of muscular reaction is below their perceptual levels. Errors occur when man is used where a machine would be better. Poor adjustment causes accidents such as when a person starts a new job and has a hard time adapting. When people are down, they cause more accidents. To stop people from causing accidents 1. direct confrontation by management, 2. training or coaching from management, and/or 3. behavior modification techniques may be used. Group norms are perhaps the single most important determinant of worker behavior. To avoid the decision to err 1. positively reinforce safe behavior, 2. build strong work groups, 3. build attitudes conducive to safety, and 4. have management that is employee centered. Quotes Schulzinger (1956) that the tendency to have accidents is a phenomenon that passes with age. It decreases steadily after reaching a peak at age 21. Men are significantly more liable to accidents than women. Irresponsible and maladjusted individuals are significantly more liable to have accidents than normally adjusted individuals. Accident prone people make up a very small part of accident statistics, less than that attributable to chance as determined by a Poisson distribution. Goes into detail on how to specifically accomplish ways to avoid errors. Each topic is delved into in detail in

separate chapters of the text. Most is involved with management theory.

Pickrel and McDonald (1964)

Feel that the extent and cost efforts to eliminate sources of human error should be commensurate with: 1. frequency with which the error is expected, 2. frequency with which a failure will occur as a result of the error, and 3. probable consequence of the failure condition. Task criticality ratings are determined from these points. Give a probability worksheet and criticality analysis, and feel that even though the method has shortcomings it is better than nothing. Feel that another method would be to come up with error probabilities.

Rasmussen (1982); Rasmussen, Pederson, Mancini, Carnino, Griffon, and Gagnolet (1981); and Rasmussen and Rouse (1981)

Say it is not good enough to study the effects of error, internal causes need to be looked at. Feel systems should be designed to tolerate error since human error can not be predicted reliably. This is consistent with Meister in the criticality of using quantitative methods for predicting error. This also implies the belief that to err is inevitable, which is stated later as human errors are the inevitable side of human adaptability. Say that centralization increases size and complexity of a system. Feel that recommendations for better training with stricter administrative controls is not the answer, better design is. This correlates to others that feel the situation causes more errors than the human alone. Caused errors are unfulfilled purposes. People find the easy way out. It is thought a solution to the cause for error has been found when something familiar is uncovered. Easy way to fix humans is to tell them to try harder but this is not a satisfactory solution. People generally don't commit errors because they want to. Most error reports are not reporting all the errors people commit. They indicate only the errors which are not corrected because they have an effect that is either irreversible or not immediately apparent to the person. Therefore, reports are biased by the potential for feedback. Say that 80-90% of the cases of errors fall into three categories: omission of steps, mistakes among alternatives (up/down, +/-), and operational "improvement"

(people making up a "better way" as they go along). People typically know what to do and when, but not always how. Omissions and inadequate consideration of latent causes or inappropriate side effects in selecting procedural steps are the two main causes of error. Suggests feedback be used whenever possible since people correct their actions when it is provided. Suggest that control panels cause errors since people have to relate dial readings to the state of the system. Such calls for interpretation and integration. A lot of this work centers around nuclear power plants. Support the multiple causation theory. "In a system of balanced design major accidents will depend on a complex chain of events including equipment faults and latent risky conditions, together with human mistakes and errors." Gives a definition of accident as: "an unwanted transfer of energy because of lack of barriers and/or controls producing injury to persons, property, or process." Quote from Johnson: "Typically the effect of exotic and unpredictable human acts is masked by the frequency of trivial equipment faults." When humans are put into a system the risk taken is not that they will cause accidents, but rather that they may not succeed in preventing them. The problem in the present context is that people in the system must be considered as system components and that human error data are needed. Say that risk analysis (as compared with reliability analysis) involves the estimation of the probability of several categories of accidental event sequences related to the relevant categories of risk such as damage to people and environment as well as to loss of major

equipment. This means that the overall probability related to a specific consequence must be calculated by a probability model derived from the family of relevant accidental event sequences together with data on the component failure modes involved. Collecting data for error rate information on humans is difficult due to feedback. Reliability of human performance in response to infrequent demands ranges from .2 to .6. Therefore error rates from general error reports will not apply to this situation. An accident is typically caused by a sneak path for events, created by the accidental timing of a considerable number of normal and erroneous human acts together with latent risky conditions and equipment failures. Define the external mode of malfunction as the immediate and observable effect of human malfunction upon task performance, as opposed to internal mode of malfunction which comes from within the person. Expand on the types of behavior and the errors classified under each: Automated skill-based behavior (types of error: task not performed, erroneous acts, and extraneous effects on other and nearby systems), Goal-oriented and rule-based behavior (types of error: deficiencies in coordinating segments of skill-based behavior, errors in recall of reference data, and mistakes among alternatives). Technique for Human Error Rate Prediction (THERP) is used here. Knowledge based, goal controlled behavior (latent effects of decisions come into play). This type of behavior can not be predicted. Regarding PSFs: "In general, it is advantageous to distinguish clearly between causes, which are changes or events followed by a change of events, and more general factors which influence the flow of events by modifying human behavior or

probabilities of response."

Sheridan (1981)

Gives a little better definition of event trees and fault trees: event trees characterize with what probabilities different major events follow other events. Fault trees characterize how Boolean "and" and "or" logic determines the various ways that major system failures might occur, the "top events" of which are transferred to event trees. Says we can't treat human error like machine error because people fail differently than machines do and objectivity is more difficult. States theory that error occurs when a person's internal model is out of calibration with the real world or when the environment causes a person to commit an error. Feels in general the world of human error research is in great disarray -- no good definition of error (changes from place to place), no pinpointed cause (different theories), different classification schemes, human errors compound each other, people correct their own errors (these last two affect probability calculations), errors in one stage of development of a project compound with others later on. Agrees with biased error reports statements. Suggests rating errors with relationship to their effect 1. safety consequences, 2. economic consequences, and 3. personal consequences. Deals with humans as monitors of automated systems and the human's detection of an error condition in the mechanical system.

Siegel (1970)

Develops eight models with various characteristics. One even incorporates both equipment and human performance so as to yield a prediction of integrated system reliability. Feels there has been little effort towards human reliability in a system context and considering human reliability with equipment reliability to get system reliability. Acknowledges that behavioral studies are considerable in number but they are restricted in application. Believes that current system operator/maintainer unreliability situations contribute to total system unreliability more than hardware unreliability situations do. Therefore, considering only equipment reliability during design phases exposes a designer to the risk of a gross overstatement of system reliability. The models are stochastic since human behavior is dynamic and can not be represented by deterministic models. Human behavior is time varying. People learn, read differently under stress, vary in ability and attitudes. Leadership and personal factors affect human performance, humans get sick and fatigued. Decision making ability affects system performance. No two humans are alike. They are very flexible and adaptive. The models are stochastic digital simulations and sequentially simulate the acts and behaviors of the operators/maintainers in a man machine system as the tasks involved in mission performance are executed. "Current performance is based on such variables as past performance, the actions of other crew members, the current stress level, the input of individual proficiencies, and random fluctuations. All models consider the impact of initially

unanticipated events such as malfunctions and emergencies on operator/system performance. Some even emphasize social interactive and group facilitative variables as well as individual performance variables."

Singleton (1972)

Feels that recent attempts to classify errors emphasizes the distinction between causes, effects, and remedies. Considers analytical techniques. Goes along with those who feel a taxonomy is needed before anything else. After practical experience with national reporting to the data base, a taxonomy would emerge. Points towards this philosophy in the techniques for improving production books. Says classifications have fallen under seven types: commission : omission; reversible : irreversible; systematic : random; detectable : undetectable; formal : substantive; recoverable by machine, man, or neither; inputs : outputs : decisions. Reviews each of these techniques from other sources and concludes that the existence of all these different techniques confirms the complexity of the problem. Discusses analytical techniques versus statistical techniques. Accidents are rare and the reporting of results is distorted. As for distribution curve fitting: "Poisson can usually be interpreted as resulting from a situation of equal risk, a negative binomial results from a situation where there are some higher risk elements all the time." Type A errors result from situations where all the elements are at a higher risk level for part of the time. The critical indicant method researches near-accidents and thus provides a larger sample size. Observation methods have a trained person investigate the accident immediately after it happens. The most obvious technique for dealing with human error is to automate. The practical situation turns out that machines are poor at error correction while people are exceptionally good

in this area. In addition, proper human factors design techniques contribute to total error reduction. Allocation of function, interface and workspace design, selection and training, overqualified personnel, rigid procedures, contingency planning, human and hardware based monitoring, working hour controls, and other conditions all are contributory to error reduction. Reiterates problems in error investigation because of two theories: 1. to err is human and 2. humans are responsible for their own actions including errors. Placing the blame is involved and people will not own up to their mistakes in general. Recognizes that humans will make errors and classifies the kinds of errors which are likely to occur. Identifies their causes and effects and devises methods of minimizing error rates and the consequences of errors.

Swain (1964, 1967, 1970, 1973)

Was the developer of THERP (Technique for Human Error Rate Prediction) a quantitative technique for predicting human reliability. Constructs a fault tree to show relationships between tasks performed by a human being. Uses the AIR Data Store (Payne and Altman 1964) along with expert judgement as to individual probabilities of success and applies probability theory to arrive at a final reliability figure. The AIR Data Store was the first attempt at a human error data base. Also had contributed to the development of SHERB (Sandia Human Error Rate Bank). Believes a data bank should come before all other research. Set up forms to be used and a filing system for all the information gathered. These techniques are used for proceduralized cases. Feels that modeling efforts have been adequate and researchers should concentrate in other areas. Says human errors occur when people 1. fail to perform a task, 2. perform a task incorrectly, 3. put in wrong task, 4. perform task out of sequence, or 5. fail to perform task in allocated time. Feels that efforts should now be concentrated on a data bank. Analysts should not consider the consequences of error in a data bank, only the probability of error. Should develop a bank first. After analysis of the bank, a taxonomy should be developed. Computerization is not universally recommended. Is the originator of the Performance Shaping Factor (PSF). Suggests making a list of PSFs and rate each one for each human error reliability analysis. This is basically a quantified subjective judgement of the PSF. Feels that forms for reporting errors and

those put in the data bank should be unstructured. Should be able to repeat the error by the description, like describing an experiment. Should record preceding tasks and following tasks. Suggests that substitution of machines for human functions often decreases rather than increases system reliability. Says the techniques for error quantification as of 1964 are trees, scaling, experimentation, and literature search. Lists the factors of error: conditions of learning, performance capacity, attention or alerting conditions, information given by instructions, feedback conditions, environmental variables, and effect of personal equipment and clothing. Feels that taxonomy and modeling techniques are needed. Says there is always a tradeoff between costs and error reduction. Says that most errors are caused by the design of the work situation rather than by incompetence, poor motivation or carelessness. Situations cause most of the errors. The situation in which a worker performs is controlled by management and can affect motivation and job satisfaction. Errors are when an action exceeds tolerable limits. Errors are inevitable unless 1. there are no tolerable limits set, 2. tolerance limits exceed the range of human variability, or 3. opportunities to commit errors are small. Says that error is a natural and inevitable function of human variability. People err because they can do so many different things in so many different ways. Feels that there is no such thing as error proneness. Recommends taking the work situation approach, that is matching a job's demands and people's abilities. Feels that preventative measures are more effective

than remedial ones. Provides a definition of error: conflicts between extra- and intra-individual factors cause errors. Types of error are 1. fails to perform task, 2. performs task incorrectly, 3. introduces extraneous task elements, 4. performs task out of sequence, or 5. fails to perform task in allotted time. Hence behavior reduces the success of system. Gives a comprehensive listing of the PSFs. Discusses research done on rest periods by the English.

VanCott and Kinkade (1971)

Discuss variable and constant errors. Provide the definitions which are commonly accepted by the discipline. This is a landmark foundational compendium of design guideline information for equipment design. Attempts to apply classical probability theory to human errors and to calculate the probability of occurrence of human error. Agree with Askren in that measurements of human characteristics follow a Gaussian distribution including errors which follow a bell-shaped curve. Allow the mean to be characterized by constant error and the standard deviation to be characterized by variable error. In the case of variable error, they feel that human errors compound linearly with go-no-go situations.

Wheale and O'Shea (1982)

Study the effect of noise on error rate. The hypothesis was that noise affects performance by increasing arousal. Extroverts scored more errors than introverts and high neuroticism scale people also had more errors. The results showed that intense noise does not have any harmful effect. In fact it masks distracting stimuli. Level of arousal was also not related to noise. It tended to stabilize and to suit task demands. Theorize that noise should have affected a short-term memory task. Intermitent noise has the greatest effect on increasing the error rate. Noise increases arousal only when the task is challenging and the noise represents a potential threat to the satisfactory completion of the task. Extroverts have sociability and impulsiveness. Impulsiveness is related to distractability which increases errors. Their final result: noise does not affect the level of arousal but the level of arousal does affect the error rate of humans.

PART II: Stress and Job Performance

Alluisi (1978)

References Chiles (1967) and his four problems of performance assessment: 1. criterion, 2. task taxonomy, 3. reliability of performance measures, and 4. role of face validity. Comments that by 1978 only problem 1. is still pertinent. Further, reports that the U.S. Supreme Court has endorsed that performance-based criteria be required for acceptance validation of selection techniques, and that a test validated on one task cannot be used for another task unless it can be shown there are no significant differences between the two tasks.

Cox (1978)

Provided are three approaches to studying stress: 1. the dependent variable is a person's response to a disturbing environment, 2. the independent variable is the stimulus characteristics of a disturbing environment, and 3. investigate the difference between the stimulus and the response as an indication of "lack of fit." Also provided is a response-based model of stress which relates a stressor-to-stress relationship to a stimulus-to-response relationship with respect to physiological and psychological forms of stress. Indicates that it has been empirically shown that conditions thought to cause stress do not always cause performance degradation. Identifies three difficulties with stimulus based definitions of stress: 1. it can not be reliably identified what aspects of real-life are actually stressful, 2. stress present in an individual can not be quantified, and 3. human variability across conditions has not been adequately investigated. Finally, the investigator is cautioned to self-examine the experimental design because it is usually not clear whether the stress exists in the eye of the subjects or in the eye of the empiricist.

Cox and MacKay (1981)

Provided is the transactional model of stress: stress is correlated to a particular relationship between humans and their environment. There are five stages in a typical stress experience cycle: 1. the relationship of the person to the sources of a demand, 2. the person's perception of the demand and his/her ability to cope, 3. the person's psychophysical reaction to the imbalance between the actual demand and the person's actual ability to cope, 4. the impact of the person's coping responses, and 5. the level and character of feedback in the loop. Generally extremes of sensory stimulation (auditory noise, heat (or lack of heat), humidity, isolation, congestion, etc.) and extremes of workload are considered to be stressful.

Embrey (1978)

Uses Meister's (1977) human performance model. States that the term stress is used indiscriminately in reliability literature. Stress is often discussed in connection with the effectiveness of a human operator in coping with various types of system emergencies. Others use stress only in explaining the effects induced when inadequate time is available to accomplish a series of tasks. Besides extreme conditions, one is also interested in the implication of stress for day-to-day reliability. States that a human functions best under conditions when there is a moderate load. The performance would be less than maximal either if the demand is too high or if the demand is too low. Suggests that Hebb's (1955) arousal theory implies that a certain amount of variety is necessary for minimizing the effects of load stress. Defines stress based on McGrath (1970) as the result of an imbalance between demand and the organism's capacity to meet that demand. States that this is, in turn, a function of the intrinsic capability of the operator, his training, and his physical state when confronted with a demand. Refers to the Eysenck Personality Inventory and its indication of extroversion and introversion personality traits. It is recommended that extremes of these traits should be avoided when placing humans in a monitoring task (calling for extroversion). Says effective training can considerably reduce stress produced by emergency situations. Presents the following measures that should be considered to ensure reliable operator performance in stressful conditions: 1. incorporation of human factors principles, 2.

selection of operators based on their ability to cope with stress, 3. emphasis on training in stressful situations, 4. provision of a task specification with a reasonable level of built-in activity in order to provide the operator with an optimal level of activation, and 5. consideration of using mediation techniques to increase the individual's resistance to stress.

Finley (1969, 1970)

Addresses the taxonomies developed by Alluisi, Miller and Meister for task analysis. Also discusses the Fleishman-Parker approach which is based on the method of differential psychology and ability identification. Took the reports of operational task analysis and used Meister's taxonomy to develop a set of 75 behavioral dimensions. These were divided into six classes: 1. individual gross body movement abilities, 2. conceptual and thinking abilities, 3. psycho-motor abilities, 4. perceptual-cognitive abilities, 5. memory functions, and 6. adjustment potential.

Hogan and Hogan (1982)

State that the Stress Activation Syndrome (SAS) entails all processes connoted by the term 'stress.' There are three components: 1. stressors, 2. stress responses, and 3. subjective or psychological factors that mediate between 1 and 2. Stressors are defined as physical (stimuli that palpably and noxiously impinge on an individual) and psychological (stimuli that generate the anticipation of harm -- either physical or social). There are five general categories of stress responses: 1. General Adaption Syndrome (GAS) which is a psychological phenomenon describing the relationship between alarm coping and exhaustion, 2. fight vs. flight where physiological changes in the GAS serve to energize the system to one or the other, 3. becoming ill which is a completely involuntary complex function of several co-occurring conditions, 4. psychosomatic disorders which lie between the realms of psychology and medicine, and 5. long term performance decrement due to a combination of illness, distractability, inattention, fatigue, and stress related abuse. Present five theories to stress: 1. emotional homeostasis -- the stressful state is characterized by emotional arousal (usually anxiety), somatic changes, and certain kinds of cognitive activity in response to stressors, 2. person to environment fit -- good match leads to high performance, expressed satisfaction, and low stress whereby a poor match leads to performance decrement, dissatisfaction, anxiety, depression, elevated blood pressure and heart rate, and somatic complaints,

3. sociological -- advocating that the causes of stress are found in the structural features of the social environment not in the individual, 4. Type A Behavior -- which is the behavior pattern characterized by excessive aggressive drive, impatience, a sense of time urgency, a compulsive need for achievement, and a need for extreme job involvement, and 5. Life Changes -- based on Social Readjustment Rating Scales (SRRS) which are currently being investigated on how they relate to illness onset. Discuss four problems with stress research: 1. personality measures are not powerfully associated with the magnitude of stress responses, 2. there is a conceptual confusion due to a lack of common terms and descriptors, hence making it difficult to correlate independent studies, 3. the fact that psychoanalysis is solving problems but not in the manner of it being research from which conclusions, results, etc. can be derived and used for the general good, and 4. there still exists an undeveloped measurement base for stress. States a socioanalytic theory of stress which conceptualizes the subjective factors which mediate stress responses by characterizing the human as a group-living and culture-using animal who needs a character structure (rules, values, and expectations) and a role structure (individual perception of rules, values, and expectations). State that stress proneness (or vulnerability) is a direct function of self esteem which is an indirect and complicated function of the character and role structures. Recommend to first establish an adequate measurement base then study the relationship among personality structure, stress vulnerability, and vocational placement.

Howarth (1978)

Provides four theoretical views of stress: 1. biological (human lifestyle differs too much from current level of adaption), 2. developmental (human is unprepared for the demands of chosen lifestyle), 3. social (exposure to conflicting social pressures compels human to play inconsistent roles, and 4. phenomenological (there is a discrepancy between the human's lifestyle and his/her aspirations).

Kahn (1981)

Presents the quality of employment survey and provides a factor structure which analyzes the importance of the job characteristics derived from the survey. A job is divided into eight basic aspects: 1. task content, 2. autonomy and control, 3. supervision and resources, 4. relations with co-workers, 5. wages and rewards, 6. promotions, 7. working conditions, and 8. organizational context. Argues that most people want to work (beyond the need for economic gain) and that deprivation of work is a stressful and potentially damaging situation.

Lazarus (1976)

Provided an interactional definition of stress: stress occurs when there is a demand which taxes or exceeds one's adjustive resources. States that frustration is a form of harm already evident in a human. Threat is anticipation of harm. Harm is physical, psychological, or social damage. Defined demand as a request or requirement of physical or mental action and implies some time restraint. Four comprehensive observations are made: 1. stress develops from a particular relationship between the person and his/her environment, 2. the social background of stress experience is a critical factor, 3. a major problem with laboratory studies is that the subjects usually are instructed (or they expect) that the stress experience is controlled and will be of short durations, and 4. there is too much ambiguity in a vast catalog of terms used in the stress area, hence making subjective response data subject to scrutiny. Coping with demands is both psychological (cognitive and behavioral strategies) and physiological. If normal coping is ineffective, stress is prolonged and abnormal responses may occur. Prolonged stress may result in functional and/or structural damage.

McGrath (1976)

States that stress occurs when a human confronts a demand which is perceived to be beyond his/her capabilities, given that the human wishes to cope with the demand. Makes the controversial

statement that situations of small disparity between the demand and one's perception of capability to cope are more stressful than the opposite.

Peterson (1980)

Refers to stress as load and breaks it into long-term and short-term categories. Short-term is defined as the present work situation. Short-term load is a function of current and outside influences and internal feelings. Factors involved are the task in itself, the psychological load e.g., task ambiguity, task success criteria, feedback, task confusion, shifting goals and tasks, environmental load, fatigue, and boredom. Long-term is defined as relating to the effect of stressors associated with life situations or current mental health. Long-term load is the relationship between a person's life situation and his likelihood of being involved in accidents.

Weitz (1970)

Provided eight sources of stress: 1. accelerated information processing, 2. noxious environmental stimuli, 3. perceived threat, 4. disrupted physiological function due to a disorder, 5. isolation and confinement, 6. blocking, 7. group pressure, and 8. frustration. Source 8 was redefined by Frankenhauzer (1975) as a lack of control over events.

Welford (1973)

Stated that stress arises whenever there is a departure from optimum conditions of demand which the person is inhibited from rectifying. Agrees with Hebb (1955) that a plot of performance versus demand is a convex parabolic curve which indicates low performance for both low and high demand.

PART III: Accidents and Safety

Anderson, R. (1983)

Discusses the data collected in slipping, falling, and tripping accidents. It induces training and experience, number of hours worked, form of payment.

Corbett (1978)

Emphasizes the need of an accident causation model based on psychological processes for adequate analysis of accidents. The logic of the psychological aspects of accident occurrences is presented as memory interpretation and identification. This logic results in sensory inputs which produce failure and incorrect output.

Craven (1981)

Emphasizes the importance of using a formal strategy in fire and explosion investigations so that evidence is not disturbed and opinionating is suppressed. Suggests a checklist of common categories of behavior [taxonomy] which may be associated with intentional fires.

Danaher (1980)

States that controller errors are not due to the mechanical systems but are due to human mistakes in attention, judgement, and communications among personnel and supervisors.

Fowler (1980)

Desires for the human error analysis problem readdressed with air traffic controllers. The idea is not to reduce error potential but to increase the number of aircraft under positive control by a single controller. The operators (controllers and pilots) must be understood and appreciated in terms of their capabilities and limitations.

Kletz (1976)

Asks for a different approach in accident data collection. Questions whether industry accident reports are ever read. States that current approach is to try to devise a means of identifying hazards so as to determine which warrant revision. Calls for a data bank which includes near-misses, and a need to train operators to better recognize human errors as they occur.

Levine (1976)

States that industrial accidents have been reduced significantly by considering the hazardous properties of machines, lighting, noise, and physiological limitations of operations. Behavioral scientists have introduced social and psychological attributes (including life situations) of workers as additional dimensions of accident etiology.

Patnoe (1978)

States that it is generally agreed in the field of accident investigation that 80% of all accidents are the result of human failure and the other 20% are attributable to mechanical failure or acts of God. States that Holmes and Rake (1967) conducted a landmark study on social stressors and the Social Readjustment Rating Scale (SRRS). States that test data from Holmes and Masuda (1974) establishes a consideration between life events of the individual and accident causation.

Piniat (1978)

There is a need to place greater emphasis on the control of unsafe acts. Examines principles of motivation theory as a potential tool for the safety professional to minimize the frequency and severity of harmful events by controlling unsafe acts. Stresses job satisfaction factors. The safety professional must be able to utilize the most valuable resource at his disposal, the employee, to optimize the efficacy of his efforts towards a safe and healthful environment.

Slovic (1982)

Refers to Wilder's theory of risk homeostasis which is a hypothesis that people have a target level of risk in different activities and these are not necessarily the same target for all activities. This will cause safety measures to be ineffective from time to time. Feels that reducing people's tolerance for risk should have a salutary effect on safety.

Smillie and Ayoub (1976)

Present a simulation modeling approach for aiding in the discovery of potential hazards that are essential for the functioning of the accident process. This model is a closed-loop system which considers the major factors of presented, expected, and perceived information, the actions of the situation, and the feedback to the human. Incorporate new features into model of Hale and Hale (1970) and include the flow of information constructed according to a multilinear events sequencing approach suggested by Brenner (1975).

Swain (1972)

States that occupational accidents are frequently written off as results of human error or poor workmanship. Provides four models: 1. single, 2. sequential, 3. logic diagram, and 4. dynamic models. Suggests that ergonomists should concentrate on making improvements in the working environment instead of making unfruitful attempts to reduce natural variations of human behavior.

Weiner (1980)

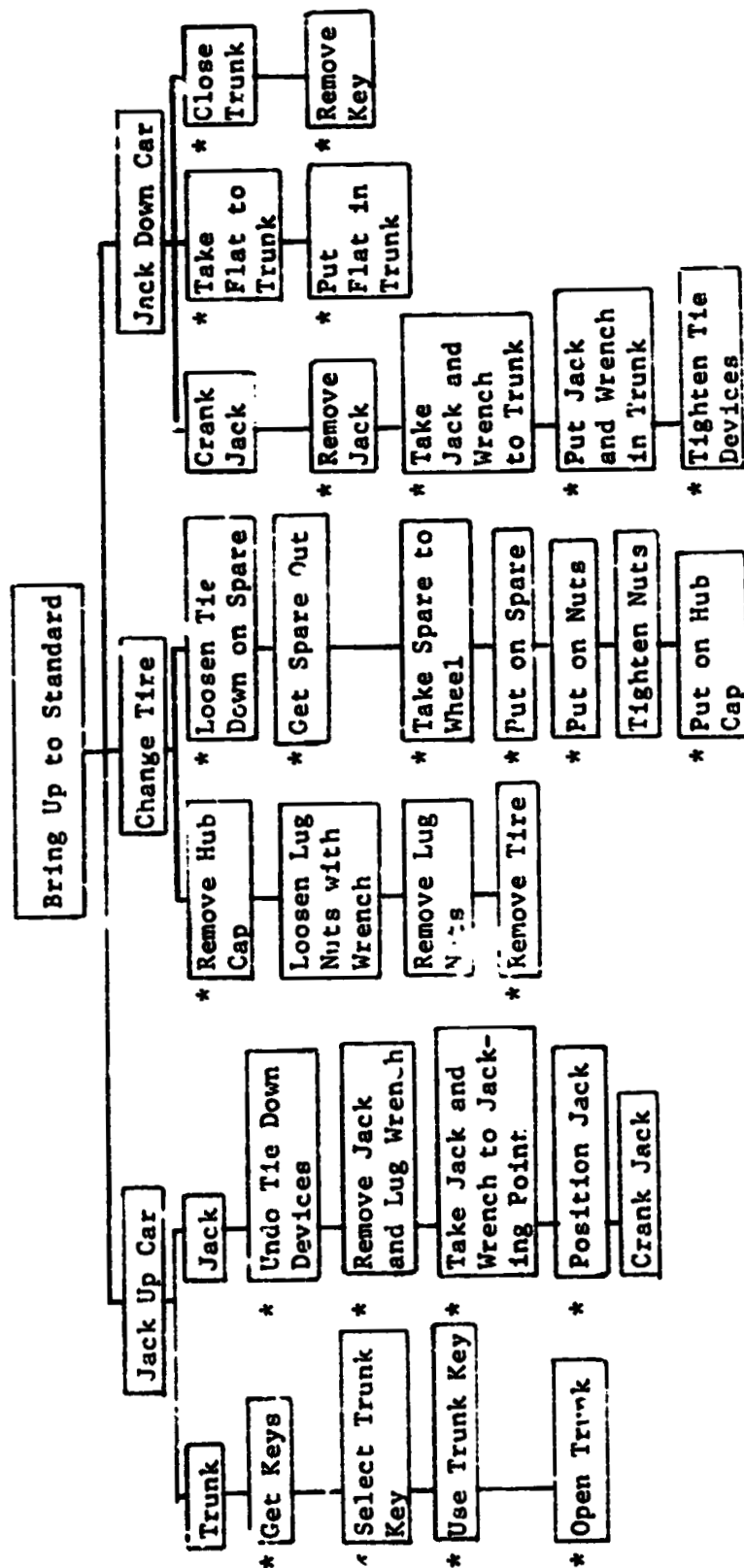
Sees airline collisions as results of system induced errors, resulting from a system that emphasizes airspace allocation and political compromise rather than dealing directly with the various problems facing controllers and pilots.

APPENDIX C

ILLUSTRATED EXAMPLE OF A TASK REVIEWED BY THE TRM

APPENDIX C: Illustrated Example of a Task Reviewed by the TRM

TASK NAME: Changing a Flat Tire
 TASK OBJECTIVE: Bring Vehicle's Mobile Support System up to Minimum Standard



[All Functions designated by an * have been allocated to humans. All others have been allocated to non-humans.]

APPENDIX D

REFERENCES

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