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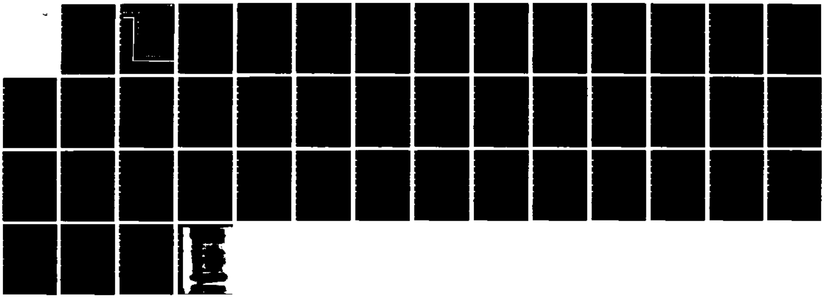

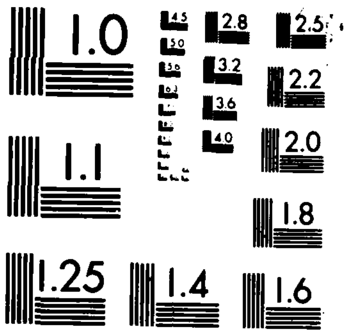


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# SAFETY TRAINING PRIORITIES

By

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MANPOWER AND PERSONNEL DIVISION
Brooks Air Force Base, Texas 78235

April 1984
Final Report



AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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The Air Force is interested in identifying potentially hazardous tasks and prevention of accidents. This effort proposes four methods for determining safety training priorities for job tasks in three enlisted specialties. These methods can be used to design training aimed at avoiding loss of people, time, materials, and money associated with on-the-job accidents.

Job tasks performed by airmen were measured using task and job factor ratings. Combining accident reports and job inventories, subject-matter experts identified tasks associated with accidents over a 3-year period. Applying correlational, multiple regression, and cost-benefit analysis, four methods were developed for ordering hazardous tasks to determine safety training priorities.

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## SUMMARY

### Objective

The objective was to determine the feasibility of developing a method for prioritizing job tasks within a specialty in terms of hazard, possibility of accidents, and other factors of concern to training designers.

### Background

Safety is a major concern on all Air Force jobs, but certain career areas are more hazardous than others. The Air Force Inspection and Safety Center at Norton AFB requested the development of methods for identifying hazardous job tasks that could be used as an indicator for improved training and thus reduce injuries and loss of equipment, time, and materials caused by on-the-job accidents. Related research and development (R&D) has frequently dealt with the study of accident proneness in individuals. While some R&D has been concerned with job-related measures, few experiments actually addressed the relation between job tasks and accidents.

### Approach

This effort deals with the identification, measurement, and prediction of accident-prone tasks for three Air Force specialties. Accident descriptions were matched to the tasks being performed when the accidents occurred. All tasks were measured by obtaining ratings from airmen and supervisory personnel on various job and task factors. A hazard-potential task factor rating scale was developed for the effort. Several regression models were tested for efficiency in predicting accident occurrence and frequency. Finally, four alternative strategies for obtaining an ordered list of hazardous tasks within a specialty were proposed.

### Specifics

*Method.* Criterion data were developed by determining which job tasks were associated with accidents. Accident data for Aircraft Armament specialists (462X0), Fire Protection specialists (571X0), and Fuels specialists (631X0) were obtained from computer files at the Air Force Inspection and Safety Center. Subject-matter specialists reviewed accident reports for each specialty covering a 3-year period from July 1975 to June 1978. They also reviewed task lists developed by the Air Force Occupational Measurement Center to determine which tasks were being performed when the accidents occurred. Dependent measures in the effort were (a) frequency of accident occurrence on a given task and (b) whether accidents occurred at all.

Predictor variables included the following task factors: hazard potential, consequences of inadequate performance, task delay tolerance, task difficulty, and field-recommended training emphasis. Data on these variables were collected by mail surveys of supervisors in the field. In addition, percentage of time spent performing a task, percentage of members performing, and weighted average military grade performance were taken from occupational survey data and included as potential predictors.

Most of the analyses were performed using Comprehensive Occupational Data Analysis Programs. These included generating various descriptive data (frequency distributions, means, standard deviations) on the variables, determining level of interrater agreement on rating factors, performing correlation and regression analyses to predict accident occurrences, and developing a cost-benefit training model.

*Findings and Discussion.* Several methods were developed for determining safety training priorities, each varying in the extent of information it makes available. The simplest method relates the accident data to the occupational survey data. Although this method identifies accident tasks, it does not identify those tasks that have not yet been associated with accidents (but are likely to be in the future). The second method uses printouts that list all tasks performed in the specialty ordered from the highest rated hazardous task through the lowest rated hazardous task. This method identifies

both tasks that have had accidents and tasks that are likely to have accidents. The third approach uses predicted scores from a safety-training regression model. This method takes into account the amount of exposure to a task as well as how many people are performing the task. The fourth method, the cost-benefit analysis, allows for the estimation of how much money might be saved if certain tasks are trained due to their accident potential, based on predicted scores.

**Conclusions**

This R&D effort brought together several tools and capabilities that already existed within the Air Force and combined them in a new way to assist the training community in identifying hazardous tasks. The expertise of subject-matter specialties was used to determine accident tasks. In addition to existing technology, new procedures were introduced. For example, a new task factor rating scale for measuring hazard potential was developed and is now available. A new computer program was also developed that has the capability of estimating training cost savings based on the number of tasks receiving safety training.

## PREFACE

This research and development was conducted under Task 2313T1, Manpower Management, and documented under Project 7719, Force Acquisition and Distribution System, and Task 771919, Analysis of Job and Mission Requirements. It was accomplished in response to Request for Personnel Research 76-35 and in support of the Force Acquisition and Distribution System thrust.

The authors wish to express their appreciation to Dr. Raymond E. Christal of the Air Force Human Resources Laboratory and to Mr. William J. Stacy, now with the Office of Civilian Personnel Operations, for their contributions to this effort.

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## SAFETY TRAINING PRIORITIES

### I. BACKGROUND

An ever present problem in all occupations is the occurrence of accidents. Wherever the human element is present, the possibility of accidents exists. The means to identify accident areas, measure the associated hazards, and eliminate the hazards, however, are elusive. A major problem in identifying hazardous situations that lead to accidents is that accident occurrences are very infrequent in relation to the frequency of performance of work tasks. Additionally, most accidents are rather inconsequential in nature. Disastrous or almost disastrous accidents are rare and, therefore, very difficult to predict. The Air Force has historically been very interested in methods for reporting and classifying accidents and near-accidents (Thorndike, 1951; Vasilas, Fitzpatrick, DuBois, & Youtz, 1953). The present study examines accidents and the tasks being performed when accidents occur; furthermore, it proposes several methods for ordering hazardous tasks to determine safety training priorities. Standard Air Force accident reports are used to aid in the identification and prediction of hazardous tasks.

#### Review of Relevant Literature

Research and development (R&D) on safety issues can be approached by studying (a) the characteristics of individuals involved in accidents, (b) the hazards associated with equipment, (c) the hazards associated with environment, and (d) the relationship of hazards to job tasks. Virtually all published studies deal with one or a combination of the first three approaches.

In a comprehensive look at the human factors involved in accidents, Thorndike (1951) concluded that there appear to be real individual differences in tendencies to have accidents. Mintz (1954) found that there may be individual differences in accident proneness among taxi drivers but that having an accident did not seem to increase the driver's accident susceptibility. Webb (1956) supported this viewpoint when he determined that accidents could not be reduced by selecting pilots on the basis of whether they had been involved in prior accidents.

In further accident proneness studies, Jenkins (1956, 1961) developed a job attitude survey as a safety index that measured personality traits of accident-prone people in industrial settings. Kerr (1950) suggested that accident proneness may be a group psychological phenomenon as well as an individual phenomenon and that a change in the psychological frame of reference to raise the level of alertness in employees might decrease accidents.

Although the human element must be considered when accidents occur, other job-related factors should be studied also. North American Rockwell Corporation (Hiltz, 1968) used fault tree analysis to identify systems failures that might lead to fatalities. Fine (1971) studied hazardous situations and proposed a risk score formula to measure these situations.

Although it is important, as a preliminary step, to identify, measure, and try to eliminate hazardous conditions, it is even more important to try to predict future accidents. Such prediction would allow for the application of preventive measures, such as training or the elimination of unsafe conditions. Goeller (1969) presented a paper at the nation's First Regional Highway Safety Conference that proposed a possible prediction model for making safety priority decisions for traffic safety systems. This model traced steps leading to an accident and predicted the impact of various safety activities.

#### Objectives

The present effort examined the safety problem by studying the relationship of the hazard potential of job tasks and other job task data to the occurrence of accidents while performing the job tasks. A major hypothesis of the study was that accident frequency for a specific task could be expressed as a joint function of hazard potential, criticality, difficulty, and exposure. An additional factor, the weighted average grade of the personnel performing a task, was also considered. It was expected that tasks performed by lower average grade personnel would be associated with more accidents because such airmen would have less experience. The purpose was to develop a method of rank-ordering job tasks in terms of hazard potential, expected occurrence of accidents, and other pertinent factors that could assist Air Force training designers in determining qualitative requirements for safety training. The specific objectives were to identify job tasks that were being performed when accidents occurred, predict which tasks would likely be associated with accidents in the future, and develop one or more methods for ordering potentially hazardous tasks.

## II. APPROACH

The approach was to assemble task inventories and accident data and to determine which tasks were being performed when accidents occurred. Data were then collected from subject-matter experts and analyses were performed to establish job task priorities in terms of safety training, to develop regression models to predict tasks requiring special safety training, and to develop a cost trade-off model for training accident-related tasks.

### Job Tasks

Job tasks performed in three different occupational specialties were the basic units of analysis used in the study. The job tasks were those defined in task inventories developed by the Air Force Occupational Measurement Center at Randolph AFB. These task listings were used because they were comprehensive and current.

The three Air Force occupational specialties chosen for study were the Aircraft Armament specialty (Air Force Specialty Code (AFSC) 462X0), formerly Weapons Mechanic, the Fire Protection specialty (AFSC 571X0), and the Fuels specialty (AFSC 631X0). They were chosen because airmen in these specialties were identified by the Air Force Inspection and Safety Center as having relatively high numbers of ground accidents (as opposed to flying accidents) as compared to other specialties.

Aircraft Armament is a large specialty consisting of approximately 12,500 airmen, about 2,400 of whom serve at a supervisory level. The work in the specialty is described by a 527-task inventory. The work deals primarily with the loading and unloading of aircraft munitions and weapons; however, it also involves performing flight-line inspections, conducting operational checks, and maintaining equipment (Burns, Barucky, & Ruck, 1976).

In the Fire Protection specialty, there are approximately 6,000 airmen, 710 of whom are supervisory personnel. Their work is described by 484 tasks. Most of the personnel assigned to this specialty work in the areas of fire extinguisher maintenance, aerospace structural firefighting and crash/rescue, fire alarm center operations, and supply (Kopala, Keeth, & Lee, 1978).

The Fuels specialty has the shortest task list (374 tasks) and is comprised of approximately 7,000 airmen, 950 of whom serve in a supervisory capacity. The major nonsupervisory jobs in this specialty are field auditing, mobile distribution and hydrant fueling, hydrant fueling/maintaining, bulk storing, cryogenics, air transportable hydrant systems, miscellaneous distribution, quality control, and flight-line monitoring (Eustis, DiTullio, Nolte, & Ruck, 1976).

### Data Collection Procedures

#### Accident Reports

Reports of accidents occurring in the three specialties were obtained from the Air Force Inspection and Safety Center, Safety Education Department, Norton AFB for the period July 1975 to June 1978. The accident reports were in narrative form, including such information as accident location and date, the cost per accident, and a description of each accident. Originally, accidents occurring from July 1975 through December 1976 in the Aircraft Armament career ladder were analyzed. Additional accident data were later collected for this career ladder for the time period of January 1977 through June 1978 to be used in a cross-validation analysis. During this second phase of data collection, Fire Protection and Fuels specialties were added to the effort to allow for cross-application of the models developed for the Aircraft Armament specialty.

As a first step in the analysis, it was necessary to identify which tasks in the job inventory were being performed when the accidents occurred. The training schools for the three specialties (Lowry AFB-Aircraft Armament; Chanute AFB-Fire Protection and Fuels) were asked to choose five subject-matter experts from each specialty. Copies of accident narratives and the job inventory task lists were mailed to the schools and the subject-matter experts were asked, as a group, to link one or more tasks with each accident and record their findings on a form provided to them.

**Task Factor Ratings**

Ratings were collected on several task factors. Task factor ratings are measurements obtained from rating scales describing various characteristics of tasks in job inventories. The task factor rating scales used in this study were (a) hazard potential, (b) consequences of inadequate performance, (c) task delay tolerance, and (d) task difficulty. The task factor survey procedure was developed at the Air Force Human Resources Laboratory (Mead, 1975; M[illegible] & Christal, 1974; Ruck, Thompson, & Thomson, 1978; Stacy, Thompson, & Thomson, 1977; Thompson & Ru[illegible] [illegible]78, 1979). This procedure provides a method for rating tasks on selected factors, collecting the ratings from supe[illegible]rs in the field and analyzing the resultant ratings.

The hazard-potential factor was designed to measure those tasks that are considered more haz[illegible] than others due to environmental, individual, or systems problems. The hazard factor was suggested in a study that [illegible]ed human effects on nuclear systems safety (Askren, Campbell, Seifert, Hall, Johnson, & Sulzen, 1976). The hazard potential rating scale is a nine-point scale which ranges from extremely low hazard potential "1" through extremely high hazard potential "9".

Consequences of inadequate performance and task delay tolerance are measures of criticality. Consequences-of-inadequate-performance measures perceived consequences in terms of destroyed material, wasted time, injury, or loss of life. It differs from hazard potential by addressing what happens when a task is incorrectly performed. Hazard potential may exist, however, even when a task is performed correctly. Task delay tolerance indicates how much time may elapse before a task must be performed to avoid serious consequences. For instance, administering emergency medical aid requires that little time may elapse before performing the tasks; whereas, a great deal of time may elapse before filling out forms. Task difficulty measures the estimated time required to learn to perform a task satisfactorily. The task factors and a description of each are shown in Table 1.

*Materials.* To collect the task factor data, survey booklets were constructed consisting of task lists and rating scales. Each survey booklet contained only one task factor rating scale. Appendix B contains survey booklet instructions and sample survey sheets. All scales were nine-point scales. For hazard potential, subjects were asked to check tasks that were applicable to the task factor scale and rate only those tasks checked. All tasks not checked were assigned zero ratings. Table A7 (Appendix A) defines the verbal anchors of each of the task factor scales.

*Respondents.* The raters for each task factor survey in all three specialties were supervisory 7- and 9-skill-level noncommissioned officers, randomly selected from personnel files. For the first administration of the new hazard-potential scale, approximately 1000 supervisors were surveyed in the Aircraft Armament specialty. For the subsequent administration of that scale, as well as the administration of the inadequate performance and delay tolerance scales, approximately 100 supervisors from the specialty areas were surveyed. The number of supervisors responding on each task factor ranged from 34 to 803, with the median number of raters across specialties being 78.

*Survey Methods.* Copies of survey booklets were printed and mailed to supervisors in the field. Distribution of booklets was accomplished by mailing the booklets to the Consolidated Base Personnel Offices (CBPOs) at selected bases. The CBPOs were then responsible for disseminating the booklets to selected supervisors and collecting completed surveys. Two months were allotted for return of the booklets, resulting in a return rate of approximately 60% of the booklets mailed out.

*Table 1.* **Identification of Task Factors, Job Factors and Criteria**

| Task/Job Factors | Description | Metric[a] | Source |
|---|---|---|---|
| **Predictors** | | | |
| Hazard Potential | A measure of tasks perceived to be more hazardous than other tasks due to factors such as consequences of inadequate performance, mechanical failure, and environmental conditions. | (0–9)[b]<br>0 No Hazard Potential<br>1 Extremely Low Hazard Potential<br>5 Average<br>9 Extremely High Hazard Potential | Field Supervisor Judgments |
| Consequences of Inadequate Performance | The perceived consequences if a task is inadequately performed, considered in terms of destroyed material, wasted *time*, *injury*, or *loss of* life. | (1–9)[b]<br>1 Minimal<br>5 Serious<br>9 Disastrous | Field Supervisor Judgments |
| Task Delay Tolerance | A measure of how much delay can be tolerated between time the airman becomes aware the task is to be performed and the time he or she must commence doing it. | (1–9)[b]<br>1 Extremely Low - Must Do Immediately<br>5 Average<br>9 Extremely High - Do When Ready | Field Supervisor Judgments |
| Task Difficulty | The time required to learn to perform the task satisfactorily. | (1–9)[b]<br>1 Extremely Low<br>5 About Average<br>9 Very Large Amount | Field Supervisor Judgments |
| Percent Members Performing | The percentage of airmen performing the task.[c] | 0–100% | Job Incumbent Data |

Table 1. (*Continued*)

| Task/Job Factors | Description | Metric[a] | Source |
|---|---|---|---|
| Percent Time Spent | A measure of an airman's work time computed from total raw ratings representing 100% of the job and expressed as a percentage of that total. | 0–100% based on relative time spent ratings (1–9) | Job Incumbent Data |
| Weighted Average Military Grade Performing | The weighted average percent grade of individuals performing each task. Percent grade is computed by dividing the number of people in a given grade performing a task by the total number of people in that grade, and averaging the percentages across grades. | Grade levels 1 through 9 | Job Incumbent Data |
| **Criteria** | | | |
| Accident Frequency | The number of accidents that occurred while performing a task during an 18-month period. | Numerical Count (1–53) | Accident Reports |
| Occurrence/Non-Occurrence | The occurrence of one or more accidents associated with tasks. | Coded 1 or 0 | Accident Reports |

[a] All scales are anchored at all points (1–9).
[b] Supervisor ratings are expressed as a mean for each task.
[c] Incumbents indicate whether or not they perform the task (1,0). Percent is calculated for a group based on 1–0.

**Job Factors**

In addition to the task factors, three job factors that were already available from historical data files were used in the analysis. These factors were chosen because they are measures of exposure to the job tasks. They represent how much time was spent on the tasks relative to other tasks and how many people were performing the tasks. These factors are potentially related to accident occurrence simply because the more a task is performed or the greater number of people who perform the task, the greater the chances for accidents to occur. The first factor was the percent of apprentices and journeymen with 1 to 48 months total active military service (TAFMS) performing each task. The second factor was percent time spent performing the task by apprentices and journeymen with 1 to 48 months TAFMS. Percent time is computed from raw 1 to 9 scale ratings and converted to percentages totaling 100% for each airman. The computation is performed by dividing each task time spent rating by the sum of time spent ratings for all tasks performed by a given airman and multiplying by 100. Typically, these individual percent time values are averaged across airmen to represent the percent time spent by a group of people for a given task. The third job factor was the weighted average military grade of individuals performing each task. This is based on the percentage of members at each level actually performing each task. Tables 1 and A7 (in the Appendix) contain additional information about the job factors.

## Analysis

In order to explore the rather complex safety data, several types of analyses were performed. Many of the analyses were accomplished using the Comprehensive Occupational Data Analysis Programs (Christal & Weissmuller, 1976; Goody, 1976; Morsh & Christal, 1966). The analyses addressed issues of identification of accident tasks, task factor reliabilities, descriptive data, accident prediction, and cost-benefit applications.

To determine task factor reliabilities or the degree of agreement among the raters, interrater agreement indices ($R_{kk}$) (Lindquist, 1953) were obtained for each task factor by specialty. Intercorrelations among the task factors, job factors, and criteria were also studied to determine bivariate relationships among the variables. The variables in combination were then evaluated using regression techniques to determine which factors were predictive of accident occurrence. Accident occurrence was defined in two ways: (a) the frequency of occurrence of accidents and (b) the dichotomous occurrence/non-occurrence of accidents. Consideration was given to predicting the probability of an accident occurring if the task were performed once; however, in order to predict probabilities, it would have been necessary to have frequency of performance data which were not available and could not be collected within the time limitations of this study.

A cross-validation analysis was applied to the Aircraft Armament specialty to find out how well the predictive efficiency of the variables held up when applied to a second set of criterion data. Cross-application analyses were also performed across the three specialties to determine how well weights from one specialty predicted the criteria in other specialties.

Finally, utility analysis was performed using cost-benefit concepts to determine at what point the greatest accident-avoidance savings could be achieved for the Air Force with minimum safety training cost. To perform the analysis, it was necessary to generate predicted scores for each task in the specialty, the reported cost of accidents, and the estimated cost of supplying safety training for each task.

# III. RESULTS

## Identification of Accident Tasks

Table 2 shows the number of accidents occurring and number of tasks incurring accidents for each specialty. One of the major problems encountered in analyzing accident data is the small number of accidents that occur and the small number of tasks involved with those accidents. Some accidents involved more than one task. Only 4.2% of the tasks for Aircraft Armament were accident tasks, 4.8% of the tasks for Fire Protection were accident tasks, and 6.2% of the Fuels tasks were accident tasks. Tables A1 thru A3 (Appendix A) list the accident tasks and the number of associated accidents for each specialty. The tasks are analyzed, listed, and performed within broader duties; therefore, the accident data were also reviewed by duty category. Tables A4 through A6 list the accident duties and number of associated accidents for each specialty.

*Table 2.* **Accident Data Summarized for Aircraft Armament Sample 1 (462X0), Fire Protection (571X0), and Fuels (631X0)**

| Specialty | Number of Tasks in Inventory | Number of Tasks Associated w/Accidents | Number of Occurrences[a] of Accidents on Tasks |
|---|---|---|---|
| Aircraft Armament | 527 | 22 | 54 |
| Fire Protection | 484 | 23 | 88 |
| Fuels | 374 | 23 | 103 |

[a]Some accidents involved more than one task. See Appendix A, Tables A1-A3.

## Task Factor Reliability

Initially, the reliabilities of the various task factors used as predictors were examined. Table 3 reports the interrater agreement ($R_{kk}$) for each task factor for each specialty. The rater agreement indices are for sample sizes of 50 raters as estimated by the Spearman-Brown formula (Guilford, 1965). Stable reliability estimates were obtained for all task factors. Apparently, the raters for each factor in each specialty were in good agreement on how to rate the tasks on the scales used. The percentage of members performing and the percentage of time spent were not subject to analyses of interrater agreement since those job factors are expected to vary considerably within a specialty.

*Table 3.* **Interrater Agreement ($R_{kk}$) of Task Factors for Aircraft Armament (462X0), Fire Protection (571X0), and Fuels (631X0)**

| | $R_{kk}$[a] | | |
|---|---|---|---|
| Task Factors | Aircraft Armament | Fire Protection | Fuels |
| Hazard Potential | .93 | .98 | .98 |
| Consequences of Inadequate Performance | .94 | .90 | .93 |
| Task Delay Tolerance | .89 | .96 | .92 |
| Task Difficulty | .93 | .97 | .95 |

[a]Rater agreement indices all based on a sample size of 50 raters and are estimated by the Spearman-Brown formula.

## Descriptive Summary

Bivariate analyses included inspection of the correlations of all task and job factors. Tables 4, 5, and 6 report intercorrelations for the three specialties. Hazard potential and consequences of inadequate performance were highly and significantly correlated ($p < .05$) in all three specialties. Correlations between the two were .70 for Aircraft Armament, .64 for Fire Protection, and .84 for Fuels. Hazard potential correlated significantly ($p < .05$) with frequency of occurrence of accidents on tasks for Aircraft Armament and for Fuels ($p<.05$), but not for Fire Protection. However, the percentage of time spent correlated significantly with frequency of occurrence of accidents for all specialties. The mean ratings and the standard deviations for each task and job factor for each specialty are listed in Table 7. Generally, the lowest mean ratings came from the hazard-potential scale and the highest mean ratings came from the consequences-of-inadequate-performance scale.

*Table 4.* **Zero-Order Correlations Among Variables for Aircraft Armament (462X0)[a]**

| Variables | Variables 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Accident Frequency | 1.00 | | | | | | | | |
| 2. Occurrence/Non-occurrence | .69 | 1.00 | | | | | | | |
| 3. Hazard Potential | .28 | .26 | 1.00 | | | | | | |
| 4. Consequences of Inadequate Performance | .17 | .19 | .70 | 1.00 | | | | | |
| 5. Task Delay Tolerance[b] | −.26 | −.25 | −.34 | −.60 | 1.00 | | | | |
| 6. Task Difficulty | −.06 | −.10 | .04 | .27 | −.14 | 1.00 | | | |
| 7. Percent Members | .39 | .39 | .33 | .29 | −.45 | −.25 | 1.00 | | |
| 8. Percent Time | .48 | .41 | .35 | .24 | −.44 | −.28 | .97 | 1.00 | |
| 9. Weighted Average Military Grade Performing | −.17 | −.20 | −.70 | −.54 | .14 | .24 | −.36 | −.35 | 1.00 |

[a]Correlations above .088 are significant at the 0.5 level, N = 527.
[b]Note that task delay tolerance is an inverted scale, with a "one" indicating low tolerance (most serious) and a "nine" indicating *high tolerance (least serious). Therefore,* the correlations with this variable are negative.

*Table 5.* **Zero-Order Correlations Among Variables for Fire Protection (571X0)[a]**

| Variables | Variables 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Accident Frequency | 1.00 | | | | | | | | |
| 2. Occurrence/Non-occurrence | .33 | 1.00 | | | | | | | |
| 3. Hazard Potential | .06 | .20 | 1.00 | | | | | | |
| 4. Consequences of Inadequate Performance | .04 | .09 | .64 | 1.00 | | | | | |
| 5. Task Delay Tolerance[b] | −.04 | −.09 | −.62 | −.81 | 1.00 | | | | |
| 6. Task Difficulty | −.02 | −.10 | −.02 | .14 | .19 | 1.00 | | | |
| 7. Percent Members | .15 | .25 | .29 | .26 | −.52 | −.58 | 1.00 | | |
| 8. Percent Time | .19 | .28 | .16 | .17 | −.39 | −.57 | .94 | 1.00 | |
| 9. Weighted Average Military Grade Performing | −.07 | −.18 | −.45 | −.25 | .46 | .65 | −.74 | −.65 | 1.00 |

[a]Correlations above .098 are significant at the 0.5 level, N = 484.
[b]Note that task delay tolerance is an inverted scale, with a "one" indicating low tolerance (most serious) and a "nine" indicating high tolerance (least serious). Therefore, the correlations with this variable are negative.

*Table 6.* **Zero-Order Correlations Among Variables for Fuels (631X0)**[a]

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Accident Frequency | 1.00 | | | | | | | | |
| 2. Occurrence/Non-occurrence | .47 | 1.00 | | | | | | | |
| 3. Hazard Potential | .14 | .29 | 1.00 | | | | | | |
| 4. Consequences of Inadequate Performance | .11 | .22 | .84 | 1.00 | | | | | |
| 5. Task Delay Tolerance[b] | −.14 | −.28 | −.41 | −.61 | 1.00 | | | | |
| 6. Task Difficulty | −.06 | −.12 | .05 | .07 | .56 | 1.00 | | | |
| 7. Percent Members | .30 | .33 | .10 | .17 | −.64 | −.65 | 1.00 | | |
| 8. Percent Time | .43 | .38 | .14 | .18 | −.54 | −.51 | .94 | 1.00 | |
| 9. Weighted Average Military Grade Performing | −.13 | −.26 | −.70 | −.64 | .65 | .37 | −.47 | −.43 | 1.00 |

[a]Correlations above .113 are significant at the 0.5 level, N = 374.

[b]Note that task delay tolerance is an inverted scale, with a "one" indicating low tolerance (most serious) and a "nine" indicating high tolerance (least serious). Therefore, the correlations with this variable are negative.

*Table 7.* **Means and Standard Deviations of Variables for Aircraft Armament (462X0), Fire Protection (571X0), and Fuels (631X0)**

| | Occupational Specialty | | | | | |
|---|---|---|---|---|---|---|
| | Aircraft Armament | | Fire Protection | | Fuels | |
| Variables[a] | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD |
| Hazard Potential | 1.87 | 1.24 | 3.81 | 1.66 | 2.07 | 2.05 |
| Consequences of Inadequate Performance | 6.16 | .86 | 5.73 | .89 | 5.13 | 1.01 |
| Task Delay Tolerance | 4.52 | .81 | 3.69 | 1.09 | 3.60 | .82 |
| Task Difficulty | 4.07 | .55 | 5.00 | 1.00 | 4.18 | .77 |
| Percent Members Performing | 12.78 | 11.16 | 20.01 | 19.58 | 10.21 | 10.75 |
| Percent Time Spent | .19 | .27 | .21 | .30 | .27 | .47 |
| Weighted Average Military Grade | 5.02 | 1.22 | 5.27 | 1.46 | 5.42 | 1.42 |

[a]Note that Task Delay Tolerance is high-to-low; all other variables are low-to-high.

The hazard potential scale was developed specifically for this effort as a predictor of accident occurrences, and the hazard potential ratings were examined in considerable detail. All the tasks in each inventory were ordered from highest to lowest on the mean (across raters) hazard potential rating. Tables A8 through A10 are extracts of the ordered listings. Included in these tables are the frequency of occurrence of accidents and data for other job and task factors. Of the accident-related tasks for the Aircraft Armament specialty, 91% had average hazard potential ratings above the grand mean for the entire specialty; 96% of the accident tasks for both Fire Protection and Fuels had mean hazard-potential ratings above the mean of their respective specialties.

## Prediction of Accidents

### Regression Models

Five regression models were tested for predictive efficiency. Table 8 lists the variables as they were used in each model. Squared variables and direct product terms were included to account for possible interactions and curvilinear relationships among the variables. The regression model including all of the predictors was labeled the task characteristics model. All multiple Rs for this model within each of the specialties were significant for both frequency of occurrence of accidents and occurrence/non-occurrence of accidents as criteria. A restricted model that was tested omitted the criticality variables (consequences and delay), the difficulty variable, and the grade-performing variable. The variables that were eliminated added no significant predictive variance except in predicting the occurrence/non-occurrence criterion for the Fuels Specialty. Table 9 lists the multiple Rs for each of these models for both criteria.

*Table 8.* **Variables Included in Prediction Models**

| Variables | Models | | | | |
|---|---|---|---|---|---|
| | Task Characteristics | Restricted | Hazard/ Exposure | Exposure | Hazard |
| 1. Hazard Potential | X | X | X | | X |
| 2. Consequences of Performance | X | | | | |
| 3. Task Delay Tolerance | X | | | | |
| 4. Task Difficulty | X | | | | |
| 5. Percent Time Spent 1-48 months | X | X | X | X | |
| 6. Percent Members Performing 1-48 months | X | X | X | X | |
| 7. Weighted Average Military Grade Performing | X | | | | |
| 8. Hazard (1) Squared[a] | X | X | X | | X |
| 9. Consequences (2) Squared | X | | | | |
| 10. Delay (3) Squared | X | | | | |
| 11. Difficulty (4) Squared | X | | | | |
| 12. Time (5) Squared | X | X | X | X | |
| 13. Members (6) Squared | X | X | X | X | |
| 14. Weighted Grade (7) Squared | X | | | | |
| 15. Hazard (1) X Time (5)[b] | | | X | | |
| 16. Hazard Squared (8) X Time (5) | | | X | | |
| 17. Hazard (1) X Time Squared (12) | | | X | | |
| 18. Hazard Squared (8) X Time Squared (12) | | | X | | |

[a]Squared terms were added to account for curvilinear relationship
[b]Interactions were added to account for the effects of two variables acting together.

*Table 9.* **Multiple Rs for Regression Models from Each Specialty Using Occurrence/Non-Occurrence and Frequency of Accidents as Criteria**

| Specialty | Criteria: Occurrence/ Non-Occurrence | Criteria: Accident Frequency |
|---|---|---|
| Aircraft Armament (462X0) | | |
| Task Characteristics | .4579** | .7609** |
| Restricted | .4498** | .7555** |
| Hazard/Exposure | .4780** | .8349** |
| Exposure | .4346** | .7487** |
| Hazard | .2300** | .4390** |
| Fire Protection (571X0) | | |
| Task Characteristics | .3722** | .2757** |
| Restricted | .3452** | .2360** |
| Hazard/Exposure | .3824** | .3795** |
| Exposure | .3151** | .2211** |
| Hazard | .2017** | .0709 |
| Fuels (631X0) | | |
| Task Characteristics | .5641** | .5865** |
| Restricted | .5124** | .5797** |
| Hazard/Exposure | .5940** | .6142** |
| Exposure | .4670** | .5778** |
| Hazard | .2872** | .1393* |

*$p < .05$.
**$p < .01$.

A third model, designated hazard/exposure, was considered. This model contained the same hazard and exposure variables as the restricted model but included several direct-product terms to account for possible interaction effects. Significantly higher multiple R's were obtained on both criteria for all three specialties indicating that the effects of hazard potential were not the same for differing levels of exposure.

In addition to the full, restricted, and hazard/exposure models, two other models were considered. The exposure model included only the percentage of time spent and the percentage of members performing. Although significantly different from zero in all cases, it was not as efficient as the hazard/exposure model for predicting accident frequency in Aircraft Armament nor was it as efficient for predicting accident occurrences in any of the three specialties. This suggested that hazard-potential data were an essential component to the prediction system. Similar comparisons between the hazard/exposure model and a fifth model based solely on hazard data indicated that the exposure data also made unique contributions to predicting accidents in all three specialties.

Based on the overall analysis, task criticality (delay tolerance/consequences of inadequate performance) and rated learning difficulty were not found to be essential components of the prediction system. On the other hand, hazard potential and exposure (percentage of time spent/percentage of members performing) were found to be essential.

Considering all of the primary predictors, the percentage of time spent accounted for the most variance in the regression models. The percentage of time spent correlated .48 with frequency of accidents in Aircraft Armament, .19 in Fire Protection, and .43 in Fuels. Standard score weights for the hazard/exposure, exposure, and hazard models using frequency of occurrence of accidents as the criterion variable are listed in Table C1 (Appendix C).

The predicted number of accidents for each task, based on regression weights derived from three of the models (hazard/exposure, exposure, hazard) and using frequency of accidents as the criterion, was computed. The tasks were then ordered from the task with the highest predicted number of accidents through the task with the lowest predicted number of accidents. Table 10 presents the cumulative percentage of actual accidents occurring at different cumulative percentages of tasks. In all models, at least 60% of the accidents were accounted for in the first 20% of the tasks. A chi-square test was run on each of the sets of predicted accident tasks to test the hypothesis that the distribution of actual accidents over predicted accidents was no better than chance. The accident distribution was found to be significantly different from chance ($\underline{p}<.01$) for each set of predictors. Table C2 gives the values for each of the chi-square tests.

*Table 10.* **Classifications of Accident Occurrences on Predicted Accident Frequency**

| Percentage of Tasks Ordered on Predicted Number of Accidents | Percentage of Accident Occurrences | | |
|---|---|---|---|
| | Hazard/Exposure Model | Exposure Model | Hazard Model |
| **1. Aircraft Armament - 462X0** | | | |
| 5 | 59 | 56 | 56 |
| 10 | 69 | 61 | 67 |
| 20 | 89 | 67 | 81 |
| 30 | 96 | 74 | 83 |
| 40 | 98 | 87 | 83 |
| 50 | 98 | 87 | 87 |
| • | • | • | • |
| • | • | • | • |
| • | • | • | • |
| 100 | 100 | 100 | 100 |
| **2. Fire Protection - 571X0** | | | |
| 5 | 70 | 67 | 7 |
| 10 | 73 | 69 | 8 |
| 20 | 78 | 75 | 82 |
| 30 | 78 | 75 | 92 |
| 40 | 82 | 76 | 98 |
| 50 | 83 | 76 | 99 |
| • | • | • | • |
| • | • | • | • |
| • | • | • | • |
| 100 | 100 | 100 | 100 |
| **3. Fuels - 631X0** | | | |
| 5 | 63 | 61 | 15 |
| 10 | 65 | 63 | 21 |
| 20 | 72 | 86 | 63 |
| 30 | 85 | 88 | 75 |
| 40 | 100 | 90 | 99 |
| 50 | 100 | 90 | 99 |
| • | • | • | • |
| • | • | • | • |
| • | • | • | • |
| 100 | 100 | 100 | 100 |

### Cross-Validation

Two groups of accident data were collected for the Aircraft Armament specialty for the purpose of conducting a cross-validation analysis. The cross-validation was performed to establish how efficiently the predictor variables would perform when applied to a second set of criterion data. The traditional cross-validation approach was not followed in this study, since the values of the predictors did not change when the second criterion (frequency of occurrence) was collected. Therefore, the first $R^2$ computed represents the best least-squares solution given the original predictors and criterion. The second $R^2$ computed represents the best least-squares solution that could be derived given the original predictors and the second criterion. The cross-validated $r^2$ is the square of the correlation between predicted scores using the initial model and the second criterion. Table 11 shows the original $R^2$ and R for each model for each sample and the cross-validation $r^2$ and r. Significant predictive accuracy was retained for all models.

*Table 11.* **Sample 1, Sample 2, and Cross-Validation Multiple Rs for Each Model with Frequency as Criterion for Aircraft Armament (462X0)**

| Model | Sample 1 | | Sample 2 | | Cross-Validation | |
|---|---|---|---|---|---|---|
| | $R^2$ | R | $R^2$ | R | $r^2$ | r |
| Hazard/Exposure | .70* | .83* | .30* | .55* | .22* | .47* |
| Exposure | .56* | .75* | .25* | .50* | .21* | .46* |
| Hazard | .19* | .44* | .13* | .36* | .14* | .37* |

*$p < .01$.

### Cross-Application

Cross-application analyses were also conducted. The regression weights for each model for each specialty were applied to task factor values for corresponding models for the other specialties. (The predicted scores for each task were correlated with frequency of accident occurrence.) Results of the cross-application analyses are reported in Table 12. Generally, the best predictions occurred when the weights from the Fire Protection specialty were applied to the data from the other two specialties. The cross-application held up best using the hazard/exposure model. There were no significant cross-applications using the hazard model.

## Utility Analysis

A utility model was developed to illustrate the application of the R&D results to the Air Force safety training community. This model was used for quantifying cost trade-offs between the actual cost of accidents to the Air Force and the estimated cost of additional safety training on those job tasks most likely to be associated with accidents. This illustration was designed to respond to the specific needs of the training community, which has the responsibility for designing training to reduce accidents. Using the Aircraft Armament specialty, it was assumed that special safety training would result in a 50% accident cost savings to the Air Force and also that the training cost would be $10 per task. These assumptions were made for demonstration purposes only and have not been validated. The regression model that was determined to be most efficient for predicting the occurrence/non-occurrence of an accident, the hazard/exposure model, was used.

*Table 12.* **Correlations for Cross-Application Analyses for Three Regression Models**

| Specialty | $r^2$ | r |
|---|---|---|
| | **Hazard/Exposure Model** | |
| 462X0 on 571X0 | .00 | .04 |
| 462X0 on 631X0 | .22** | .47** |
| 571X0 on 462X0 | .65** | .81** |
| 571X0 on 631X0 | .17** | .42** |
| 631X0 on 462X0 | .07 | −.27 |
| 631X0 on 571X0 | .03 | −.18 |
| | **Exposure Model** | |
| 462X0 on 571X0 | .02 | −.13 |
| 462X0 on 631X0 | .29** | .54** |
| 571X0 on 462X0 | .26** | .51** |
| 571X0 on 631X0 | .12* | .35* |
| 631X0 on 462X0 | .18** | −.42** |
| 631X0 on 571X0 | .04 | −.20 |
| | **Hazard Model** | |
| 462X0 on 571X0 | .00 | .05 |
| 462X0 on 631X0 | .01 | .11 |
| 571X0 on 462X0 | .04 | .20 |
| 571X0 on 631X0 | .02 | .14 |
| 631X0 on 462X0 | .05 | .23 |
| 631X0 on 571X0 | .01 | .07 |

*$p < 0.5$.
**$p < 0.1$.

The utility analysis had three major components: a predicted accident score, a cut-off score, and a utility score or cost. Tasks were first ordered from high to low probability of accident occurrence based on predicted scores from the regression model. The utility analysis addressed the question of how many tasks should be included in training to minimize the total costs associated with training and accident occurrence. To answer the question, an overall cost value was derived incrementally as each additional task was considered for training. The overall cost at each iteration was obtained by multiplying the number of tasks above the cut-off score by the assumed cost of training ($10), adding half of the accident costs of those tasks above the cut-off score, and adding the total accident costs of those tasks below the cut-off score.

If the cut-off score were set at zero, all tasks would be trained. The utility at this point would be 527 tasks X $10 (cost of training all tasks) plus .5 X $18,162 (half the cost of accidents), which would equal $14,351. On the other hand, if the cut-off score were set at one, no tasks would be trained, and the utility would equal $18,162 (the total cost of theaccidents).

The minimum overall cost was found to be $10,428, representing a $7,734 savings. Using this cut-off, the utility model identified correctly 19 of the 21 actual accident tasks. It also identified as accident tasks 59 tasks (false positives) which did not have accident occurrences during the 18-month time span. If this model were adopted, a total of 78 tasks would be singled out for special safety training.

## IV. DISCUSSION

### Findings

The task factors that were used in this effort, (hazard potential, consequence of inadequate performance, task delay tolerance, and learning difficulty), each had high interrater agreement. Low interrater agreement on any task factor would have precluded that factor from being used in the predictive models because of its instability. Two criteria, occurrence/non-occurrence of accidents and frequency of occurrence of accidents, were used during the course of this effort. The relationships between the criteria and the predictors were essentially the same for both criteria.

Only two predictors were significantly correlated with the frequency of accident occurrence criterion for all three specialties: percentage of time spent, and percentage of members performing. Task delay tolerance, consequences of inadequate performance, weighted average military grade, and hazard potential were significantly correlated with the criterion in the Aircraft Armament and Fuels specialties but not in the Fire Protection specialty. One factor that may have contributed to low correlations in the Fire Protection Specialty was that 60% of the accidents were attributed to one task, "Drive fire-fighting vehicles." The highest accident task for Fuels was "Drive tank trucks," which accounted for 39% of the accident occurrences; and the highest accident task for Aircraft Armament was "Arm or dearm aircraft armament systems other than guns," which accounted for 20% of the accident occurrences. The "better" distributions of accidents on tasks for Aircraft Armament and Fuels allowed for the higher correlations. The nonsignificant correlation between hazard potential and frequency of occurrence of accidents was probably due to the extremely skewed distribution of the occurrence of accidents across tasks. With this kind of distribution, the percentage of accident tasks occurring above the mean hazard rating was probably more representative of the nature of the data than of the correlation. More than 90% of the accident tasks were above the mean for all three specialties.

The hazard/exposure model was generally more successful than the other models; therefore, it is recommended for future use. It requires the collection of only three predictors: hazard potential, percentage of time spent, and percentage of members performing. It might be noted that the exposure model was almost as good as the hazard/exposure model in cross-validation and cross-application. Although this might argue for the exposure model, it seems more credible to recommend the hazard/exposure model, which includes expert opinions about the hazard potential of tasks in addition to exposure.

There was moderate shrinkage in multiple Rs from sample 1 to sample 2 in the cross-validation analysis due to problems in the criteria. The problems could have been attributed to (a) inaccuracies in matching accidents to task statements, (b) inaccuracies in the accident reporting system, or (c) true changes in the occurrences of accidents from the first sample to the second sample. However, the accident/task matchings were made by motivated experts under controlled conditions, and the Air Force accident system is reliable (due to controls over time or money lost due to injuries or damaged equipment); consequently, it is reasonable to assume that the shrinkage is due to the actual nature of the accident data.

The cross-application analyses showed that the prospects for developing a general regression model for predicting accidents for all specialties are dim. Finding a generalizable model was not a main objective of this effort. Specialized research design for this objective might result in different findings.

### Applications

Several methods of rank-ordering hazardous job tasks for the three Air Force specialties were developed. By using the method of relating accident data to occupational survey data, the subject-matter specialists for each job specialty identified tasks that were involved with accidents. These accident tasks could be singled out for special safety training. The major disadvantage of this method is that it does not consider those tasks which have not yet had accidents but are likely to. However, the advantage is that the method pinpoints where accidents are occurring using data that are currently available for all specialties.

The second method of ordering tasks is to use the hazard potential scale to obtain field supervisory judgments of what tasks are considered the most hazardous. A listing of all tasks in the inventory can be obtained ordered from the highest hazard task through the lowest hazard task. The tasks identified with this method include those that have previously been associated with accidents as well as those that have not been associated with accidents but are likely accident tasks in the opinion of expert judges.

The safety training hazard/exposure regression model is a third way to identify hazardous tasks. The three main variables in this model are hazard potential, percentage of time spent, and percentage of members performing for individual tasks. This method takes into account the amount of exposure to a task and also how many people are performing the task. From the regression model, a list of predicted scores can be obtained for the tasks and the predicted scores ordered from the highest through the lowest predicted scores for the tasks in the inventory. This model is useful because it takes into account the time variable and the number-of-people-performing variable, both of which are significantly correlated with the frequency of accident occurrence.

Coupling the results of the regression analysis with the cost-benefit analysis adds an extra dimension to the process of identifying and ordering tasks. Based on the hazard/exposure model using occurrence/non-occurrence of an accident as the criterion, this type of analysis allows for the estimation of how much money might be saved if certain tasks were singled out for safety training.

## V. CONCLUSIONS

This R&D effort was concerned with the identification, measurement, and prediction of accident tasks for the following Air Force job specialties: Aircraft Armament, Fire Protection, and Fuels. A method was developed to identify the accident tasks using occupational survey data, accident reports, and subject-matter specialists in the field. The accident tasks were evaluated against ratings of several task and job factors, including hazard potential which was developed specifically for this effort. Prediction of accident tasks was tested using several regression models. Four strategies for prioritizing hazardous tasks within a specialty were proposed.

The following procedures appear to be feasible:

1. Matching descriptions of accident occurrences with job tasks.

2. Evaluating hazard potential by eliciting supervisor judgments.

3. Estimating accident occurrences by considering hazard potential and exposure.

4. Applying cost-minimization strategies to the problem of determing which tasks to train.

The hazard-potential scale and the techniques developed in this effort are specialized tools that would be of value in those job specialties where accidents are most frequent and costly in terms of loss of life, time, and material. Of the four techniques described, the accident task matching and the ordering of tasks on the hazard potential scale are the simplest to accomplish. The regression models and cost-benefit analysis are more sophisticated and time-consuming, but also render more information about the nature of the tasks and the costs for safety training. Any of these techniques would be beneficial to the training community if tailored to the specific needs of the job specialty.

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## *APPENDIX A:* DESCRIPTIVE DATA

*Table A1.* **Accident Tasks for Aircraft Armament Sample 1 (462X0)**

| Task Number | Description | Accident Frequency |
|---|---|---|
| E136 | Initiate, make entiries on, or review Maintenance Data Collection Record Forms (AFTO Form 349) | 1 |
| F162 | Arm or dearm aircraft armament systems other than guns | 11 |
| F163 | Complete munitions post load inspections or procedures | 2 |
| F164 | Inspect, connect, or disconnect mechanical lanyards or disconnect while loading or unloading | 1 |
| F166 | Inspect non-nuclear munitions prior to loading on aircraft or preload stands | 2 |
| F170 | Load or unload non-nuclear munitions prior to loading on preload stands or racks | 9 |
| F174 | Perform functional checks or tests on aircraft armament circuits while loading | 3 |
| F176 | Perform pre-maintenance safety checks of munitions | 2 |
| F177 | Prepare non-nuclear munitions for loading on aircraft or preload stands | 2 |
| G187 | Inspect cockpit weapons release system electrical or electronic components | 1 |
| H230 | Perform operational checks of jettison or emergency release systems using meters or indicators | 3 |
| H231 | Perform operational checks of missile launch and control system using built-in test equipment | 1 |
| H233 | Perform operational checks of missile launch and control systems using meters or indicators | 1 |
| H234 | Perform operational checks of non-nuclear bombing systems using built-in test equipment | 1 |
| H235 | Perform operational checks of non-nuclear bombing systems using external programmed test equipment | 1 |
| H237 | Perform operational checks of photoflash dispensing systems | 1 |
| Q404 | Adjust munitions handling equipment or AGE (aerospace ground equipment) mechanical component | 1 |

Table A1. (*Continued*)

| Task Number | Description | Accident Frequency |
|---|---|---|
| Q457 | Install supporting and securing devices on munitions for transport or shipment | 3 |
| Q460 | Load or unload non-nuclear munitions onto or from transport or shipment | 3 |
| Q461 | Operate munitions to load or unload munitions handling equipment | 1 |
| Q462 | Operate munitions handling equipment to transport munitions | 1 |
| Q463 | Perform munitions transfer procedures | 3 |

*Table A2*. **Accident Tasks for Fire Protection (571X0)**

| Task Number | Description | Accident Frequency |
|---|---|---|
| D5 | Conduct burning pit exercises | 5 |
| D8 | Conduct egress training from aircraft or building | 1 |
| D17 | Conduct wet hose drills | 1 |
| D18 | Demonstrate operations of fire fighting equipment | 4 |
| F2 | Drive fire-fighting vehicles | 53 |
| F10 | Operate hand or booster lines | 1 |
| F11 | Operate nozzles | 1 |
| F15 | Perform master stream operations | 1 |
| G8 | Inspect carbon dioxide ($CO_2$) systems | 1 |
| K6 | Control or extinguish structural fires | 1 |
| K17 | Make forcible entries into building | 1 |
| K18 | Operate structural fire-fighting vehicles | 1 |
| L28 | Stand by runways during aircraft landings or takeoffs | 3 |
| M20 | Rescue personnel from motor vehicles | 2 |
| N11 | Service ramp patrol vehicle extinguishing systems | 1 |
| O1 | Change tires on fire-fighting vehicles | 1 |
| O3 | Clean or maintain station facilities | 1 |
| O8 | Perform maintenance on extinguishing systems | 2 |
| O11 | Perform operator maintenance on fire-fighting vehicle mounted equipment | 1 |
| O12 | Perform operator maintenance on fire-fighting vehicles | 2 |
| P7 | Recharge $CO_2$ fire extinguisher | 1 |
| P19 | Remove, replace, or repair extinguisher cart tires | 1 |
| S17 | Remove or install webbing, arresting cables, or pendants of MA-1A systems | 2 |

*Table A3.* **Accident Tasks for Fuels (631X0)**

| Task Number | Description | Accident Frequency |
|---|---|---|
| G189 | Connect or disconnect off-loading hoses from railway tank cars, trucks, or trailers | 1 |
| G190 | Dispose of unsuitable products | 1 |
| G194 | Fill mobile refueling units from bulk storage | 4 |
| G197 | Inspect loaded bulk fuel compartments or containers of delivering carriers | 1 |
| G200 | Inspect tanks selected to receive fuel | 12 |
| G202 | Inspect unloaded bulk fuel compartments or containers of delivering carriers | 1 |
| G203 | Monitor hoses, valves, or pumps during receiving operations | 6 |
| G205 | Position off-loading valves at proper locations | 6 |
| H219 | Drive tank trucks | 40 |
| H220 | Drive tractors | 1 |
| H221 | Drive tractor-trailer combinations | 1 |
| H225 | Fuel aircraft with modified Panero hydrant systems | 1 |
| H226 | Fuel acraft with Panero hydrant systems | 1 |
| H227 | Fuel aircraft with Phillips hydrant systems | 1 |
| H228 | Fuel aircraft with Pritchard hydrant systems | 8 |
| H233 | Fuel or defule aircraft with R-2 Condec tank trucks | 1 |
| H234 | Fuel or defuel with R-2 Heil tank trucks | 1 |
| H235 | Fuel or defuel aircraft with R-5 tank trucks | 2 |
| H237 | Fuel or defuel aircraft with R-9 tank trucks | 4 |
| I263 | Perform operator maintenance on bulk storage systems | 2 |
| I270 | Perform operator maintenance on Pritchard hydrant systems | 2 |
| I271 | Perform operator maintenance on tank trucks | 5 |
| K307 | Inspect to insure proper vehicle operator maintenance has been performed | 1 |

*Table A4*. **Accident Duties for Aircraft Armament Sample 1 (462X0)**

| Duty | Description | Accident Frequency |
|---|---|---|
| E | Working with forms, records, reports, directives, and technical data | 1 |
| F | Loading and unloading munitions and weapons on aircraft | 32 |
| G | Performing flight-line inspections of aircraft suspension, release, launch, and monitor and control systems | 1 |
| H | Performing operational checks of aircraft suspension, release, launch, and monitor and control systems | 8 |
| O | Maintaining equipment and aerospace ground equipment (AGE) | 1 |
| Q | Shipping and transporting munitions | 11 |

*Table A5*. **Accident Duties for Fire Protection (571X0)**

| Duty | Description | Accident Frequency |
|---|---|---|
| D | Training | 11 |
| F | Performing general fire protection duties | 56 |
| G | Inspecting fire alarm systems, automatic installed sprinkler systems, and fire prevention devices | 1 |
| K | Fighting structural fires (frame and masonry) | 3 |
| L | Fighting aerospace vehicle fires | 3 |
| M | Performing rescue operation | 2 |
| N | Servicing and testing equipment and installed systems | 1 |
| O | Maintaining equipment | 7 |
| P | Maintaining and repairing fire extinguishers | 2 |
| S | Performing maintenance on runway barriers | 2 |

*Table A6*. **Accident Duties for Fuel (631X0)**

| Duty | Description | Accident Frequency |
|---|---|---|
| G | Receiving bulk fuels | 32 |
| H | Issuing bulk fuels | 61 |
| I | Performing operator maintenance | 9 |
| K | Perform quality control functions | 1 |

*Table A7.* **Task and Job Factors Scales**

1. Hazard Potential

**Rating Scale**

| | |
|---|---|
| 1 | Extremely low hazard potential |
| 2 | Very low |
| 3 | Low |
| 4 | Below average |
| 5 | Average |
| 6 | Above average |
| 7 | High |
| 8 | Very high |
| 9 | Extremely high hazard potential |

2. Probable Consequences of Inadequate Performance

**Rating Scale**

| | |
|---|---|
| 1 | Minimal (inadequate performance has minimal consequences) |
| 2 | Slight |
| 3 | Not very serious |
| 4 | Fairly serious |
| 5 | Serious |
| 6 | Very serious |
| 7 | Extremely serious |
| 8 | Almost disastrous |
| 9 | Disastrous (indequate performance has disastrous consequences) |

3. Task Delay Tolerance

**Rating Scale**

| | |
|---|---|
| 1 | Extremely low |
| 2 | Very low |
| 3 | Low |
| 4 | Below average |
| 5 | Average |
| 6 | Above average |
| 7 | High |
| 8 | Very high |
| 9 | Extremely high (can wait for a long time) |

4. Task Difficulty

**Rating Scale**

| | |
|---|---|
| 1 | Extremely low |
| 2 | Very low |
| 3 | Low |
| 4 | Below average |
| 5 | About average |
| 6 | Above average |
| 7 | High |
| 8 | Very high |
| 9 | Extremely high |

Table A7. (*Continued*)

5. Time Spent

**Rating Scale**

| | |
|---|---|
| 1 | Very small amount |
| 2 | Much below average |
| 3 | Below average |
| 4 | Slightly below average |
| 5 | About average |
| 6 | Slightly above average |
| 7 | Above average |
| 8 | Much above average |
| 9 | Very large amount[a] |

[a] Actual percent time spent is computed from the time spent scale and expressed as a percent.

*Table A8*. **Selected Tasks Ordered from High to Low Mean Hazard Potential Ratings - Aircraft Armament (462X0)**

| Duty | Task | Title | Sequence Number | Hazard Potential | Accident Frequency | % Members 1-48 Mos Service | % Time 1-48 Mos Service | Consequences of Inadequate Performance |
|---|---|---|---|---|---|---|---|---|
| F | 162 | Arm or dearm armament aircraft armament systems other than guns | 1 | 6.2 | 11 | 62 | 1.9 | 7.5 |
| F | 170 | Load or unload non-nuclear munitions on aircraft or preload stands or racks | 2 | 5.9 | 9 | 57 | 1.6 | 7.8 |
| S | 487 | Assemble practice bombs | 26 | 4.3 | 0 | 3 | .0 | 5.7 |
| J | 295 | Remove, install, or replace pylons or adaptors | 90 | 2.9 | 0 | 47 | 1.0 | 6.5 |
| H | 235 | Perform operational checks of non-nuclear bombing systems using external programmed test equipment | 261 | 1.9 | 0 | 17 | .2 | 6.9 |
| K | 332 | Perform TO modifications to bomb racks, ejector racks, or shackles | 261 | 1.9 | 0 | 17 | .2 | 6.9 |
| O | 404 | Adjust munitions handling equipment or AGE mechanical components | 338 | 1.6 | 1 | 17 | .2 | 6.0 |
| P | 431 | Issue or receive test equipment | 429 | .4 | 0 | 38 | .9 | 4.5 |
| | | $\bar{X}$ (all tasks) | | 1.87 | .10 | 12.78 | .19 | 6.16 |
| | | SD (all tasks) | | 1.24 | .71 | 11.16 | .27 | .86 |

*Table A9*. **Selected Tasks Ordered from High to Low Mean Hazard Potential Ratings - Fire Protection (571X0)**

| Duty | Task | Title | Sequence Number | Hazard Potential | Accident Frequency | % Members 1-48 Mos Service | % Time 1-48 Mos Service | Consequences of Inadequate Performance |
|---|---|---|---|---|---|---|---|---|
| M | 19 | Rescue personnel from launch pads or launch control facilities | 1 | 8.0 | 0 | 7 | .0 | 7.6 |
| K | 6 | Control or extinguish structural fires | 14 | 7.2 | 1 | 56 | .5 | 7.1 |
| D | 5 | Conduct burning pit exercises | 39 | 6.3 | 5 | 8 | .1 | 7.0 |
| F | 2 | Drive fire fighting vehicles | 109 | 5.2 | 53 | 76 | 1.3 | 6.2 |
| L | 21 | Remove foam from runways | 226 | 3.9 | 0 | 27 | .2 | 3.7 |
| N | 3 | Flush agent tanks on fire fighting vehicles | 256 | 3.7 | 0 | 61 | .7 | 5.1 |
| O | 16 | Schedule fire-fighting equipment for depot repairs | 336 | 2.8 | 0 | 6 | .0 | 5.2 |
| B | 6 | Develop or maintain status boards or graphs | 484 | 1.1 | 0 | 19 | .2 | 4.3 |
| | | $\bar{X}$ (all tasks) | | 3.81 | .18 | 20.01 | .21 | 5.73 |
| | | SD (all tasks) | | 1.66 | 2.44 | 19.58 | .30 | .89 |

*Table A10.* **Selected Tasks Ordered from High to Low Mean Hazard Potential Ratings - Fuels (631X0)**

| Duty | Task | Title | Sequence Number | Hazard Potential | Accident Frequency | % Members 1-48 Mos Service | % Time 1-48 Mos Service | Consequences of Inadequate Performance |
|---|---|---|---|---|---|---|---|---|
| J | 284 | Issue LOX (liquid oxygen) to oxygen carts | 1 | 6.4 | 0 | 28 | .7 | 6.9 |
| H | 237 | Fuel or defuel aircraft with R-9 tank trucks | 17 | 5.6 | 4 | 35 | 2.1 | 6.6 |
| H | 219 | Drive tank trucks | 54 | 4.9 | 40 | 53 | 3.3 | 6.1 |
| L | 372 | Sample LN2 (liquid nitrogen) | 79 | 4.4 | 0 | 3 | .0 | 6.4 |
| G | 200 | Inspect tanks selected to receive fuel | 141 | 2.9 | 12 | 20 | .4 | 5.8 |
| A | 1 | Assign personnel to duty positions | 217 | .5 | 0 | 8 | .1 | 4.0 |
| E | 101 | Annotate Bulk Fuel Issue/Defuel Summary forms (AF Form 1232) | 284 | .2 | 0 | 27 | .9 | 4.5 |
| E | 158 | Initiate RCS reports | 374 | .1 | 0 | 4 | .1 | 4.4 |
| | | $\bar{X}$ (all tasks) | | 2.07 | .28 | 10.21 | .27 | 5.13 |
| | | SD (all tasks) | | 2.05 | 2.27 | 10.75 | .47 | 1.01 |

## *APPENDIX B:* SURVEY BOOKLET INSTRUCTIONS AND SAMPLE ANSWER SHEETS

### Hazard Potential
### INSTRUCTIONS

1. Explanation: In the Air Force some tasks are more hazardous to perform than others. For example, the possibility of a serious accident occurring while loading munitions is much more likely than while estimating budget requirements. Some tasks have a higher "hazard potential" than others due to a variety of factors such as the consequences of inadequate performance of the task, possibility of mechanical failure, environmental conditions, etc. This booklet contains a listing of supervisory and worker level tasks performed in your career ladder. You are asked to evaluate each task to indicate the "hazard potential" of the task.

2. Please complete this booklet in two steps:

   Step 1. Read through the list of task statements and check any task which you consider to have a hazard potential. Make your checks in the CHECK (✓) column, to the right of the listed task statements.

   Step 2. After the completion of Step 1, rate only the tasks you checked to indicate how potentially hazardous you feel each task may be. Using the following 9-point rating scale, make your ratings by writing the numbers 1 through 9 in the HAZARD POTENTIAL column. For example, if you think a task has "extremely high hazard" potential, then write the number "9" next to the task.

| Rating Scale | Hazard Potential |
|---|---|
| 1 | Extremely low hazard potential |
| 2 | Very low |
| 3 | Low |
| 4 | Below average |
| 5 | Average |
| 6 | Above average |
| 7 | High |
| 8 | Very high |
| 9 | Extremely high hazard potential |

3. Your efforts in completing this booklet will be sincerely appreciated. When you have finished your ratings, please return this booklet to your CBPO/DPMPC.

| JOB INVENTORY (DUTY - TASK LIST) | AFSC 462X0 | PAGE 10 OF 33 PAGES | |
|---|---|---|---|
| CHECK (✓) AND RATE ANY TASK WHICH YOU CONSIDER POTENTIALLY HAZARDOUS.<br><br>F. LOADING AND UNLOADING MUNITIONS AND WEAPONS ON AIRCRAFT | CHECK ✓ | HAZARD POTENTIAL<br>1. Extremely Low<br>2. Very Low<br>3. Low<br>4. Below Average<br>5. Average<br>6. Above Average<br>7. High<br>8. Very High<br>9. Extremely High | |
| 1. Arm or dearm aircraft armament systems other than guns | | | 28 |
| 2. Complete munitions post load inspections or procedures | | | 29 |
| 3. Inspect, connect, or disconnect mechanical lanyards or disconnects while loading or unloading | | | 30 |
| 4. Inspect, connect, or disconnect munitions electrical cables while loading or unloading | | | 31 |
| 5. Inspect non-nuclear munitions prior to loading on aircraft or preload stands | | | 32 |
| 6. Inspect nuclear weapons prior to loading on aircraft or preload stands | | | 33 |
| 7. Inspect shackles or bomb racks for operation or damage during loading | | | 34 |
| 8. Inspect suspension gear such as pylons, rails, or racks prior to loading | | | 35 |
| 9. Load or unload non-nuclear munitions on aircraft or preload stands or racks | | | 36 |
| 10. Load or unload nuclear weapons on aircraft or preload stands or racks | | | 37 |
| * * * * * * * * * * | | | |
| 11. Load or unload preloaded non-nuclear munitions on aircraft | | | 38 |
| 12. Load or unload preloaded nuclear weapons on aircraft | | | 39 |
| 13. Perform functional checks or tests on aircraft armament circuits while loading | | | 40 |
| 14. Perform post maintenance safety checks of munitions | | | 41 |
| 15. Perform pre-maintenance safety checks of munitions | | | 42 |
| 16. Prepare non-nuclear munitions for loading on aircraft or preload stands | | | 43 |
| 17. Prepare nuclear weapons for loading on aircraft or preload stands | | | 44 |
| 18. Preposition munitions prior to loading on aircraft or preload stands | | | 45 |
| | | | |
| | | | |
| | | | |

Consequences of Inadequate Performance
INSTRUCTIONS

## Explanation

This booklet contains a listing of tasks performed in your career ladder. You are asked to rate each task to indicate the Probable Consequences of Inadequate Performance of the task. In the Air Force, the consequences of inadequate performance of some tasks are much more serious than for other tasks. For example, if inadequate performance of a task will almost certainly cause an aircraft to crash, or a warehouse to burn down, or an airman to die, this would be more serious than inadequate performance of a task which merely causes incovenience and irritation. As another example, the probable consequences of inadequate performance in responding to a fire alarm would be much more serious than the probable consequences of inadequate performance in folding hospital linen.

## Definition

Consequences of Inadequate Performance is a measure of the seriousness of the probable consequences of inadequate performance of a task. It is measured in terms of possible injury or death, wasted supplies, damaged equipment, wasted man-hours of work, etc.

## Your Task

Using the rating scale below, assign a numerical rating to each task in this booklet which you feel describes the probable consequences of inadequate performance of the task. Make your ratings by simply writing a number 1 through 9 in the column to the right of each task. Please attempt to rate all tasks.

## Rating Scale

If the task is not done correctly, the probable consequences of inadequate performance would be:

1. Minimal (inadequate performance has minimal consequences)
2. Slight
3. Not very serious
4. Fairly serious
5. Serious
6. Very serious
7. Extremely serious
8. Almost disastrous
9. Disastrous (inadequate performance has disastrous consequences)

Your efforts in completing this booklet will be sincerely appreciated. When you have finished your ratings, please return this booklet to your CBPO/DPMPC.

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|---|---|---|

If the task is Not done correctly, the Probable Consequences of Inadequate Performance would be:

G. RECEIVING BULK FUELS

PROBABLE CONSEQUENCES OF INADEQUATE PERFORMANCE

1. Minimal
2. Slight
3. Not Very Serious
4. Fairly Serious
5. Serious
6. Very Serious
7. Extremely Serious
8. Almost Disastrous
9. Disastrous

| | | |
|---|---|---|
| 1. Clean or store storage facility equipment such as gauging equipment, wrenches or other tools | | 50 |
| 2. Clean receiving strainers after operations | | 51 |
| 3. Connect or disconnect grounding or bonding on barges | | 52 |
| 4. Connect or disconnect grounding or bonding on railway tank cars, trucks or trailers | | 53 |
| 5. Connect or disconnect off-loading hoses from barges | | 54 |
| 6. Connect or disconnect off-loading hoses from railway tank cars, trucks or trailers | | 55 |
| 7. Dispose of unsuitable products | | 56 |
| 8. Drain accumulation of water from delivery vehicles | | 57 |
| 9. Drain water from storage tanks | | 58 |
| 10. Examine fuel and take hydrometer readings during multiple product shipments by pipe lines | | 59 |
| * * * * * * * * * * | | |
| 11. Fill mobile refueling units from bulk storage | | 60 |
| 12. Gauge shipments for water using pole or tape and paste | | 61 |
| 13. Gauge tanks for fuel quality and temperatures | | 62 |
| 14. Inspect loaded bulk fuel compartments or containers of delivering carriers | | 63 |
| 15. Inspect meters for correct operation | | 64 |
| 16. Inspect shipments for type fuel, sediment, or water | | 65 |
| 17. Inspect tanks selected to receive fuel | | 66 |
| 18. Inspect unloaded bulk fuel compartments or containers of delivering carriers | | 67 |
| 19. Monitor hoses, valves, or pumps during receiving operations | | 68 |
| 20. Perform dock watch during ocean tanker off-loadings | | 69 |
| * * * * * * * * * * | | |

(Continued next page)

Task Delay Tolerance
INSTRUCTIONS

## Explanation

This booklet contains a listing of tasks performed in your career ladder. You are asked to rate each task to indicate the Task Delay Tolerance. Task Delay Tolerance is a measure of how much delay can be tolerated between the time the airman becomes aware that the task must be performed and the time actual performance must begin.

For some tasks encountered by airmen, no delay can be tolerated between the time the need for the task becomes evident and the time actual performance must begin. The airman who encounters the task must be able to do it then, without any delay to read up on the task or find someone to advise him. For other tasks, some delay is acceptable while the airman gets advice, checks Technical Orders, etc.

## Examples

Some examples of tasks having low Delay Tolerance and which must be performed without delay are:

Use artificial respiration to restore breathing.
Pull ripcord of emergency parachute if main parachute fails.
Extinguish fire in aircraft engine during startup on flight line.

Some examples of tasks having higher task delay tolerance, and for which some delay to get advice or read an instruction manual would be acceptable, are:

Review books for unit library.
Clean and lubricate typewriter.
Refill fire extinguisher after use.

## Your Task

Using the rating scale below, assign a numerical rating to each task in this booklet which you feel describes the appropriate task delay tolerance. Make your ratings by simply writing a number 1 through 9 in the column to the right of each task. Please attempt to rate all tasks.

## Rating Scale

1. Extremely low delay (must do immediately)
2. Very low
3. Low
4. Below average
5. Average
6. Above average
7. High
8. Very high
9. Extremely high delay (can wait for a long time)

Your efforts in completing this booklet will be sincerely appreciated. When you have finished your ratings, please return this booklet to your CBPO/DPMPC.

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|---|---|---|

Rate each task to indicate the amount of time a person can delay before starting to perform the task.

**TASK DELAY TOLERANCE**

1. Extremely Low Delay
2. Very Low
3. Low
4. Below Average
5. Average
6. Above Average
7. High
8. Very High
9. Extremely High Delay

F. PERFORMING GENERAL FIRE PROTECTION DUTIES

| | | |
|---|---|---|
| 1. Dry hoses | | 44 |
| 2. Drive firefighting vehicles | | 45 |
| 3. Establish amount of work lines for fires | | 46 |
| 4. Establish equipment positions | | 47 |
| 5. Establish positions to fight fires | | 48 |
| 6. Hook up or unhook hoses at fire hydrants | | 49 |
| 7. Hook up or unhook hoses at water tankers | | 50 |
| 8. Load hoses or make hose load finishes | | 51 |
| 9. Operate extinguishers | | 52 |
| 10. Operate hand or booster lines | | 53 |
| * * * * * * * * * * | | |
| 11. Operate nozzles | | 54 |
| 12. Operate powered wood or masonry saws | | 55 |
| 13. Operate pumper drafts or pressure controls | | 56 |
| 14. Perform fire vehicle relay operations | | 57 |
| 15. Perform master stream operations | | 58 |
| 16. Perform reverse hose lays | | 59 |
| 17. Perform siamese or wye connection hose lays | | 60 |
| 18. Perform straight hose lays | | 61 |
| 19. Place vehicle hose crossovers | | 62 |
| 20. Position or operate smoke ejectors | | 63 |
| * * * * * * * * * * | | |

(Continued next page)

# APPENDIX C: TECHNICAL DATA

*Table C1.* **Standard Score Weights for Predictor Variables from Equations with Frequency as Criterion**

| Specialty | Predictor Variables | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Haz | %Mem | %Time | $Haz^2$ | $\%Mem^2$ | $\%Time^2$ | HXT | $H^2XT$ | $HXT^2$ | $HX^2T^2$ |
| **Hazard/Exposure Model** | | | | | | | | | | |
| Aircraft Armament | −.2400 | .0364 | −.4888 | .2403 | −.4107 | 1.0979 | 3.6470 | −4.7548 | −3.6545 | 5.3083 |
| Fire Protection | −.1288 | .2204 | −.0333 | .2808 | −.1316 | .4374 | 1.1794 | −3.8334 | −1.8008 | 4.0781 |
| Fuels | .2160 | .2171 | .8375 | −.1934 | −.6258 | −1.0517 | −1.6897 | 4.7098 | 1.3134 | −3.1723 |
| **Exposure Model** | | | | | | | | | | |
| Aircraft Armament | | 1.8280 | −1.2908 | | −2.6477 | 2.7988 | | | | |
| Fire Protection | | −.5399 | .2867 | | .4887 | −.0704 | | | | |
| Fuels | | .7494 | −.1180 | | −1.1997 | 1.1263 | | | | |
| **Hazard Model** | | | | | | | | | | |
| Aircraft Armament | −.5641 | | .9121 | | | | | | | |
| Fire Protection | .1977 | | −.1364 | | | | | | | |
| Fuels | .2105 | | −.0747 | | | | | | | |

*Table C2.* **Chi-Square Values for Difference from Chance for the Distribution of Actual Accidents over Predicted Scores**

| Models | Chi-Square Values | | |
|---|---|---|---|
| | 462X0 | 571X0 | 631X0 |
| Hazard/Exposure | 161.73* | 189.72* | 199.38* |
| Exposure | 80.62* | 169.73* | 184.82* |
| Hazard | 128.58* | 217.92* | 168.61* |

*$p < .01$.



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