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Organizational Factors in Accident Risk Assessment

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A web-based system for assessing command climate and cultural factors has been in use by the US Navy for about 3 years. This system enables naval commands to administer a safety climate survey to their unit personnel and to receive immediate diagnostic feedback of results. This paper reviews the development, validation, and application of this web-based system, and discusses the findings and implications of safety climate results. It is of particular interest to the long-term goal of this study to understand the possible influence of such organizational factors as command climate and safety culture on individual behavior, including risk perception, risk-taking, and unsafe behavior that may increase the chances of an accident. The military aviation environment has afforded an opportunity to closely observe high-risk organizations, their management of flight safety, differences in safety cultures, and the potential impact of such organizational factors on flight crew risk decisions.

INTRODUCTION

The US Navy aircraft mishap rate for serious accidents has declined substantially over the past fifty years of Naval Aviation. Just twenty years ago, the mishap rate stood at about 10 aircraft losses for every 100,000-flight hours. The loss rate has dropped steadily over the years to its present level of about two aircraft per 100,000-flight hours. While the accident rate has declined appreciably, the number of aircraft losses due to aircrew factors, or human error, has stayed relatively constant. The US Naval Safety Center reports that about 60% of the U.S. Navy and U.S. Marine Corps class 'A' aircraft mishaps (those resulting in death, permanent disability, or loss of \$1 million or more) are caused by aircrew errors. In many instances such aircrew errors were preceded by unsafe conditions that were sometimes not recognized or not adequately handled by command supervisors. Schmidt (1996) showed that supervisory, leadership or organizational factors could be identified in over half of the so-called aircrew caused mishaps. Some examples of the supervisory factors listed by Schmidt included inadequate command supervision of flight operations or safety, failure to correctly assess mission risks, and poor handling of a known hazardous condition.

Much attention has been paid over the past few years to understanding human error in complex systems, including issues related to faulty human engineering of aircraft cockpits, instances of poor pilot judgment, and failures related to

breakdowns of crew communication. Relatively little has been accomplished to date concerning the potential contribution of organizational factors on aircrew flight deck performance and safety. Research conducted at the, Navy Postgraduate School, Monterey California, is one attempt to focus on key organizational issues in order to improve our understanding of the possible influence that organizational factors may have in the chain of events leading to an accident. The concept of "high-reliability-organizations" originated by Dr. Karlene Roberts, and others at UC Berkeley, was used as a point of departure for understanding how different organizations manage accident risk. High-reliability organizations are those that are very successful at reducing risks associated with hazardous operations

High-reliability Organizations

Factors that contribute to an organization's high-reliability performance have been discussed extensively in the literature (Ciavarelli and Figlock, 1997, Roberts 1993, 1990, Sagan 1993, and others. Also, social scientists and safety experts have begun to move away from the idea that accidents are simply the result of errors made by a system's operator or maintainer. The so-called "human error" accident, in many cases is rooted in antecedents that are not necessarily in the hands of the worker. Research and analysis by notable individuals have changed our thinking about assigning responsibility only to the more obvious active agent in an accident.

There is a growing interest in understanding the influence on safety outcomes of such "organizational factors" as leadership commitment to safety, organizational structure, production pressure, and safety climate and safety culture. Individuals contributing to our understanding of "organizational factors" include pioneers, such as Turner (1978), who gave us the concept of organizational "incubation periods" preceding major man-made disasters, and Perrow (1984), who suggested that organizations which conduct hazardous operations, like air transportation systems and nuclear facilities, have grown so complex, that accidents may be inevitable, or even "normal". More recently, the works of Reason (1997, 1990), and his associates, Maurino, Reason, Johnston, and Lee (1997), have brought the possible influence of organizational factors on accident causation into sharper focus, with their depiction of the "organizational accident." Their paradigm of accident causation includes the linkage among *active* failures (errors made by operators and maintainers), and *latent* failures (failures due to organizational deficiencies and poor managerial decisions). Such latent failures are thought to affect an organization's defenses, and therefore make human error at the operational end possible and in some cases more likely.

The counter to the emergence of organizational accident risk factors is to identify such latent failures before they lead to the development of an accident chain. Karl Weick and his associates (1999) claim that a key attribute of high-reliability organizations is "collective mindfulness". HRO organizations achieve low accident rates through keen awareness of their risks, close monitoring of high-risk operations, and encouragement and use of standardized procedures, and continuous training.

An important component of the High-reliability organization is the organization's *safety climate*. The *Safety climate* is considered to be a subset of overall organizational climate. Safety climate refers to the shared perception of the people in an organization that their leaders are genuinely committed to safety of operations, and have taken appropriate measures to communicate safety principles, and to ensure adherence to safety standards and procedures (Zohar, 1980). Included in our concept of a high-reliability organization are factors related to the underlying *safety culture* of the organization. An organization's safety culture is defined as the

shared values, beliefs, assumptions, and norms which may govern organizational decision making, as well as individual and group attitudes about danger, safety, and the proper conduct of hazardous operations. Culture becomes the driving force and it provides the guiding principles behind an organization's goal structure, a means to attain goals, the source of criteria for measuring progress, and the origination of methods for correcting deviations from norms and expected outcomes. Culture is passed on to successive generations of an organization's members, and culture molds behavior of individuals through a system of rewards, expectations about status, power, authority, established group boundaries for inclusion or exclusion, and underlying concepts for managing deviations from norms.

Culture is learned by individuals who join an organization and is strongly influenced by the organization's structure and leadership (Schein, 1990). An organization's culture is heavily influenced by what leaders pay attention to, and by what they express as the core values or expectations of personnel under their supervision. In the Navy, for example, our aviation officers have a tradition of a "can do" attitude, and a reputation for completing missions assigned in spite of danger and adversity. Simply landing an aircraft at night, perhaps with the ship's deck pitching, may say enough about this aspect of their culture. Naval Aviators develop a high degree of peer loyalty and loyalty to their command. To some extent such peer loyalty may affect the willingness of some aviators to report observed safety violations. Also, there is considerable latitude as to the day-to-day management and decision making at the unit level in our Naval Forces. Leaders in a particular command set the tone for a healthy command climate, and reinforcement of the safety culture. Differences in command climate and safety culture among commands may be a root source of certain unsafe attitudes and behaviors. Naval aviators themselves are characterized as strongly motivated and confident individuals that constantly strive to achieve excellence in their aviation and leadership skills. Such underlying cultural traits are thought to influence the attitudes and behavior of our aircrews in areas related to risk taking, competitiveness, the perception of danger, certain decisions regarding safety of flight -- including perhaps a decision violate flight rules.

Research conducted by Zohar (2002), Flin, Mearns, O'Connor & Bryden (2000) and Mearns, Whitaker & Flin (2003) has help shed light on differences between the two concepts of safety culture and safety climate. These authors consider the term climate a "surface feature" of culture that is more concrete and amenable to measurement than safety culture.

Finally, it is unfortunate that we often must wait until "after the fact", or the actual occurrence of an accident, before it becomes apparent that safety processes have failed. As J. Reason has stated, *Safety is defined and measured more by its absence than its presence* (Reason, 1997, p. 3). Typically, the level of safety risk is judged on the basis of such things as the accident rate, property losses, lost work time, and other safety outcome measures.

There is considerable interest among safety experts regarding the need to develop improved methods for measuring the level of safety risk in a given organization in advance of the occurrence of an untoward event. A safety audit, which examines the existing structure and functioning of operational procedures and safety processes, is one means to assess "organizational safety risk". Sometimes the safety audit is accompanied by a so-called "climate or culture" survey. Typically such surveys are constructed for application to a specific organization, and are limited with respect to the survey's theoretical foundation, and in most cases lack any form of statistical validation. These shortcomings make it difficult to apply such tailored climate or culture surveys in the general case of assessing organizational risk. There is much room for improving the use of organizational survey methods as a means to assess safety risk and perhaps with ancillary risk assessment applications needed to address security issues, financial loss potential, mission operational risks, and engineering program risk.

The proposed survey system, consisting of a validated survey questionnaire and an Internet technology foundation, would provide a means for administering such surveys via the Web, and for administrative personnel to obtain immediate feedback of survey results. It is of particular interest to the long-term goal of this study to understand the possible influence of such organizational factors as command climate and safety culture on individual behavior, including

risk perception, risk-taking, and unsafe acts, that may increase the chances of an accident.

METHOD

High-reliability theory

A Model of Organizational Safety Effectiveness was derived primarily from the works of Dr. Roberts, (1990), and her colleague Dr. Libuser (1994), who identified five major areas regarding the effectiveness of organizations in managing risk. The following conceptual framework, adapted from their work was used to formulate safety climate survey questionnaire items. Four model components are defined, as (1) **Process Auditing** - which is a system of ongoing checks to identify hazards and correct safety problems. (2) **Reward System** - or the expected social rewards and disciplinary actions used to reinforce safe behavior, and correct unsafe behavior. (3) **Quality Control** - which includes the policies and procedures for promoting high quality of work performance. (4) **Risk Management** - which includes accurate risk perception, as well as a systematic process used to identify hazards and control operational risks. (5) **Command Control** - which reflects the organization's overall safety climate, leadership effectiveness, and the policies and procedures used in the management of operations.

Survey Questionnaire

A 61- item *Command Safety Assessment Survey Questionnaire* was developed to correspond to this Organizational Effectiveness Model. The Aviation Command Assessment Survey Questionnaire uses a Likert-type, seven-point, rating scale that requires respondents to rate each of the questionnaire items as to the level of agreement (i.e., Strongly Disagree, Disagree, Neutral, Agree, Moderately Agree, Strongly Agree, or Not applicable).

A secure web-based questionnaire administration system and database was developed and is in current use today in ongoing studies of US Navy and Marine Corps units. The system is designed to protect the identity of the respondent and to ensure confidentiality of data and results for Naval Commands. The present 61-item survey was derived from an original paper version, following initial survey instrument reliability and validation tests described previously by

Ciavarelli, Figlock, Sengupta and Roberts (2001). The resulting web survey, now in use by US Navy and US Marine aviation can be viewed at, <http://avsafety.nps.navy.mil/safesurv.htm>.

RESULTS

Data Set

Data used in this analysis was drawn from a data set of 6,900 completed survey questionnaires, collected, using the Navy's online survey system. Survey data collected from July 25, 2000 to December 6, 2001 were analyzed for this particular study. The survey sample extracted was adjusted to remove spurious duplications and to take into consideration other data anomalies (resulting from systematic computer errors). The resulting sample of 6559 surveys consisted of aircrew members from the US Navy, US Marine Corps (4,364 commissioned officers and 1997 enlisted personnel) and an additional 198 respondents from other services (Densai, 2003).

Validation tests

The overall Cronbach-Alpha reliability for the survey instrument is 0.97. The Guttman split-half reliability test value was 0.95. Cronbach-Alpha reliability tests were also run for each of the four model subscales, with reliability coefficients ranging from 0.85 to 0.95. Exploratory factor analysis (principal components) was conducted, and preliminary results indicated a five-factor solution would explain about 62% of the variance. Additional validation efforts are underway to refine the factor analysis findings, and to establish relationships between safety climate survey results and organizational safety performance.

Summary key findings for US Naval Forces

Selected descriptive statistics are shown in Figure 1 and 2. Figure 1 shows the distribution of Likert rating total scores for all respondents. There is a notable, near-normal distribution of Likert ratings. Figure 2 shows statistically significant differences between personnel of different military ranks ($p < .001$), indicating more positive ratings from senior commissioned (O4 - O6) and senior enlisted ranks (E-6-E-9).

US Navy and Stanford University Study

Gaba, Singer, Sinaiko and Ciavarelli (2003) compared results of safety climate survey questions from this survey sample to results of healthcare respondents. A climate survey containing a subset of 23 similar questions was administered to employees from 15 hospitals, and results were compared to results from naval aviation. For each question a "problematic response" was defined that suggested an absence of a safety climate.

Overall the problematic response rate was 5.6% for naval aviators, versus 17.5% for hospital personnel ($p < 0.0001$). The problematic response was 20.9% in high-hazard domains such as emergency department or operating room. Problematic response among hospital workers was up to 12 times greater than among aviators on certain questions.

DISCUSSION

The accident rate for Naval Aviation since 1999 has been approximately 1.5 per 100,000 hours flown. This rate has dropped from approximately 50 per 100,000 hours in the 1950s. While greater than the accident rate in commercial aviation, this rate is very low considering the complexity of the aircraft, the hazardous missions flown, and the unique demands of carrier-based launch and recovery. This reduction is due in part to improved communication processes that result in early detection of potential accident precursors. The concept of collective mindfulness then, proposed by Karl Weick (1999) would argue for a system of organizational assessment and planned intervention as one approach to prevention. The Aviation Command Safety Assessment climate survey, which incorporates many of the measurable dimensions of high-reliability organizations, is proposed as an integral part of such an evaluation and intervention process.

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Figure 1: Distribution of Likert Scale Total Scores for all Survey Items

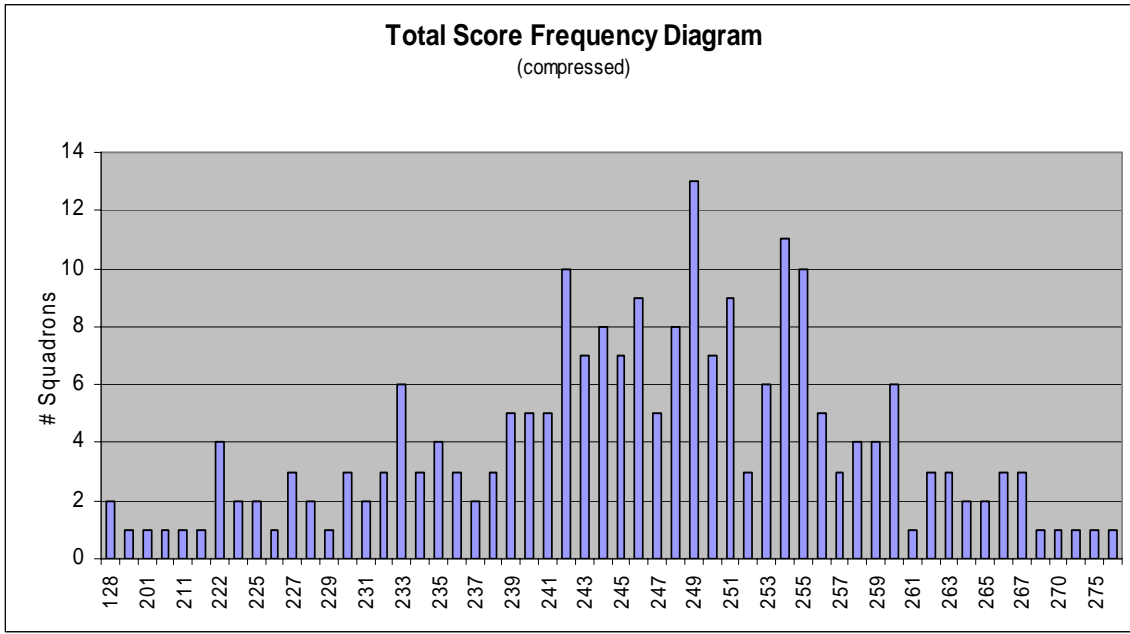


Figure 2: Chart showing Military Rank Differences

