CRITICAL INTERFACES BETWEEN ENVIRONMENT AND ORGANISM IN CLASS A MISHAPS: A RETROSPECTIVE ANALYSIS

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Aircraft-mishap prevention efforts in the past have been extremely successful. Since 1970 the mishap-rate decrease has leveled off. Most experts agree, however, that it can be further reduced. This study focuses on the human-factors aspects that have consistently played a prominent role in mishap causation but only recently have received significant scrutiny. The approach taken in this study has as its premise that both the environment and the organism bring with them a certain degree of mishap potential and that a mishap occurs as a result of the additive effects, or critical interfaces, of the two. Determining these

20. ABSTRACT (Continued)

critical interfaces by retrospective analysis of past mishaps is the method used here, the immediate goal being to identify more clearly the root cause of human-factors mishaps. Recommendations are offered for future efforts to avoid these critical interfaces or to decrease the mishap potential inherent in the environment and the organism.

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1. To the USAF School of Aerospace Medicine (USAFSAM) for foresight and courage in assuming the leadership role in the broad area of human-factors aspects in aircraft accident investigation. The significant contribution of time and resources reflects a real commitment to the premise that technology is only valuable in its application to real-world problems. That commitment has made this study possible.

2. To the Air Force Inspection and Safety Center (AFISC) for gracious hospitality and cooperation in providing the data source, the facilities, and the resources of two divisions--Life Sciences and Reports and Analysis--toward completion of this study. The remarkable success of AFISC in preventing mishaps is largely attributable to constant readiness to pursue new approaches in determining mishap causation.

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INTRODUCTION

Background

Efforts to reduce USAF aircraft mishaps in the last 30 years have been dramatically successful. Based on number of mishaps per 100,000 flying hours, the Class A (major) mishap rate has been decreased from 36.2 in 1950 to 2.8 in 1977. A curve depicting mishap-rate decrease as a function of time quite appropriately resembles a standard learning curve if inverted (Fig. 1). Indeed, we have learned much. Improvements in aircraft design and materials, training, standardized procedures, and enlightened attitudes have helped reduce the mishap rate by a factor of 1 despite the fact that the years of greatest rate decrease were also the years of greatest exposure in terms of hours flown. During the same time period, while the annual mishap rate decreased by a factor of 12, the annual cost of mishaps has more than doubled. That a cursory knowledge of world economics can explain this trend is of little consolation, and no preventive value. What has been more difficult to explain is why directed efforts have failed to continue the rate decrease.

During the early 1970's, the mishap rate leveled off at around 2.8 and has remained about at that level to date. To further compare this portion of the rate-decrease curve with a standard learning curve, this leveling would infer that either the task has been mastered or the limits of the capacity to improve have been reached. Clearly the former is not the case, since mastery of the task equates to zero accidents. A stronger case can be made for the latter in that the precarious interface between human nature and mother nature will invariably result in some mishaps, usually accompanied by or attributed to that elusive ingredient called "chance." This ingredient will be discussed later.

Few experts will concede, however, that the current rate of 2.8 represents mere chance occurrence or that we have reached the limit of our capacity to prevent mishaps. On the contrary, retrospective analysis of mishaps indicates that most were entirely preventable. Given that 1) intact and operational defense resources are, by any applied standard, far superior to smoking holes in the ground, and 2) we have not reached the limit of our capacity to further reduce occurrence of major mishaps, then it behooves us to explore new approaches in mishap prevention which will address the factors that have stagnated the rate of mishaps at its current level. The most fertile of these new approaches lies in the area of human factors.

Human factors is the scientific study of the physical, physiological, psychological, psychosocial, and pathological limitations of man as he interfaces with his environment. The specific aspects of man's makeup addressed in this definition are the topics of several extant disciplines which, taken separately, have significantly contributed to effective mishap-prevention measures. Hundreds of independent studies and papers have been published addressing various facets of these disciplines, all claiming "human factors"

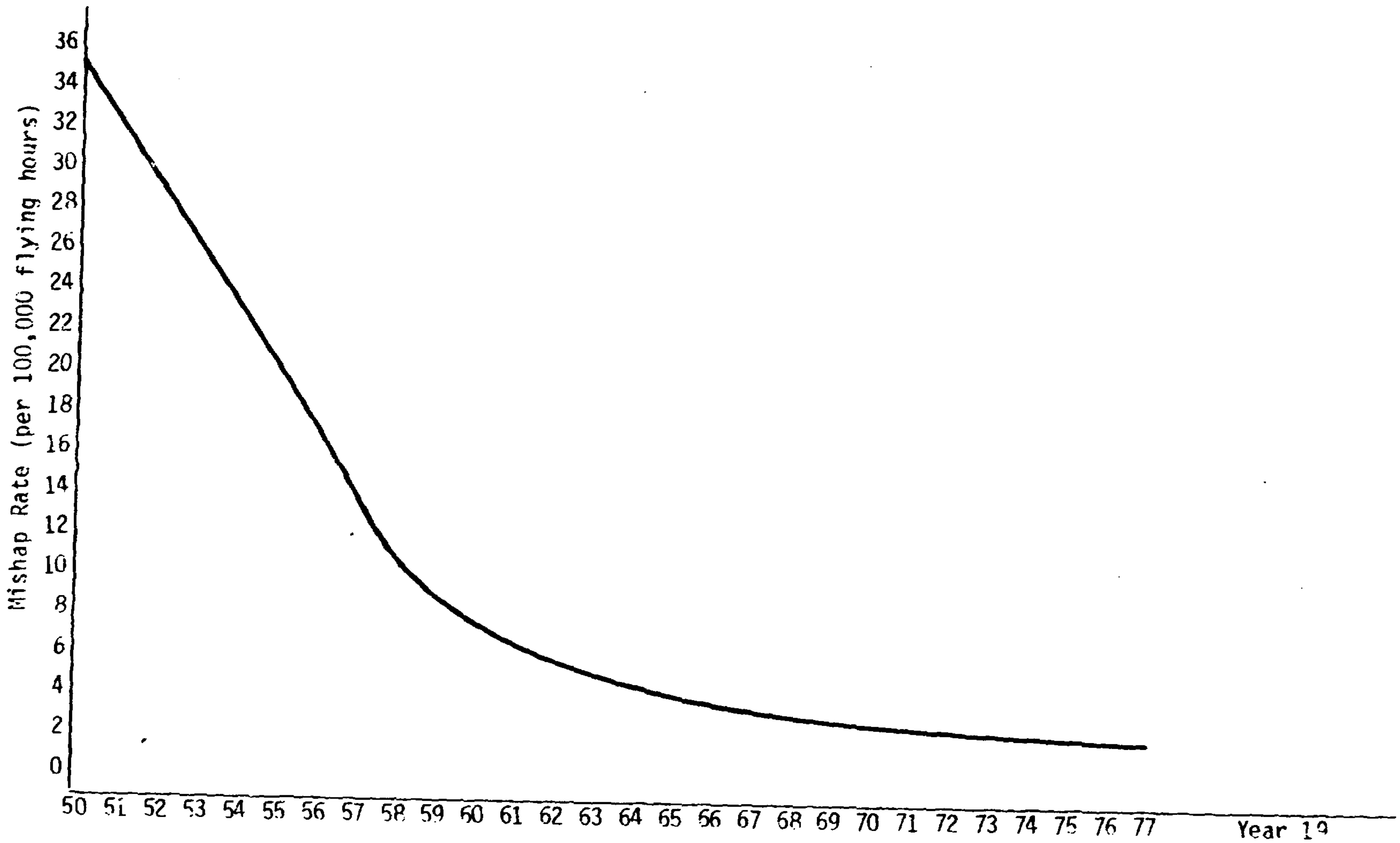

Figure 1. Decrease in rate of USAF aircraft Class A mishaps. (Average curve)

as their subject area--and validly so in the sense that human factors encompasses their subject area, but not so in the sense that human factors is limited to it.

Although only limited practical applications have been made as a result of these efforts in a variety of disciplines, such applications have been instrumental in mishap-prevention success. Human factors is unique in that it applies the knowledge gained from these disciplines to the practical aspects of man's inherent limitations and how these limitations moderate the degree to which he is able to cope with his environment. This approach has evolved from a popular misnomer and universally acknowledged trend in the field of mishap prevention, namely, "pilot error."

One of the most consistent statistics that has emerged from extensive studies of causative factors in mishaps is that 50% to 70% of all mishaps are caused by pilot error. This statistic is not unique to Air Force studies; it is common to all studies of aviation mishaps. As far as providing meaningful insight into mishap causation though, this term fails on several counts. First, it sometimes, but not often, serves as a catchall category for mishaps whose real cause is uncertain, complex, or embarrassing to the system. Second, to state that the pilot erred is gross oversimplification in that nearly all operator-induced mishaps consist of a long line of errors, only the last of which was committed by the pilot. "Human error" is a more accurate term, although it also overlooks a third misleading factor in that "erring" is equated to failure to properly perform a given task. If the demands of the task exceed the pilot's capacity, then, in fact, he has not erred. On the contrary, he has performed to his design limitations. The error was in the system that failed to recognize these limitations and then take necessary steps to either increase the pilot's capacity or reduce the demands. An excellent treatment of this concept is provided by Dr. Zeller (1, p. 18).

If human error is to be the focus of the efforts to further reduce aviation mishaps, we must begin a systematic, coordinated investigation of the complex and dynamic interactions between man and his environment as they apply to aviation in general and, more specifically, to the mission of the U.S. Armed Forces. This is the arena of human factors research, and herein lies the future hope of more effective mishap prevention.

Purpose and Scope

The goal of this study is to discover the salient factors contributing to a limited category of human error mishaps--limited in that ultimately all mishaps involve some element of human error, whether they occur in the air or on the ground, and certainly all mishaps will not be considered here. Attention will be focused on the category of mishaps that accounts for the majority of USAF aircraft Class A mishaps; namely, those where cause has been attributed to the operator. (Class A mishaps are those whose damage cost exceeds $200,000 or in which a fatality has occurred or an aircraft was destroyed.) This study is further limited in that it scrutinizes only mishaps occurring in a relatively short time period. The sample in this time period, however, is the entire population of Class A aircraft mishaps. Furthermore, this time period is typical of similar time periods from 1970 to date--the period of mishap-rate stagnation. A definitive solution to the problem of reducing the mishap rate is beyond the scope of this study. The purpose here is to define the driving parameters behind operator-induced mishaps and to provide some direction for future intensified efforts.

Approach

Our approach is based on the premise that both the environment and the organism contain a certain degree of inherent mishap potential. The terms "environment" and "organism" are used slightly differently here than in the familiar "man-machine-environment" model. "Environment" comprises variables with which the organism must cope--the machine, the weather, and the complex social system which trains, equips, motivates, orients response modes, and otherwise generates stimuli to be detected, analyzed, and acted upon by the organism. "Organism," on the other hand, comprises the tools that allow the operator to perform the task--the physical, physiological, psychological, and psychosocial makeup of man. Each organism has varying capacities of each parameter. Although the two cannot be separated in the real world, they can be analyzed independently on an academic basis.

The environment and the organism form a dynamic system in constant flux. As the organism acts on the environment, they are both inexorably changed; and the process begins again. When a fire light shines in the cockpit, the innumerable previous interfaces between the organism and environment, moderated by a current prevailing few and the limits of the pilot's current capacity to cope, largely determine what action the pilot will take. This varies from the "man-machine-environment" model in that, in our concept, the machine is taken as another part of the environment with which the man must cope, not as a separate entity in itself. All of this is to say that human events do not occur randomly nor independently of each other. Even the track of a dust particle in a hurricane can be accurately predicted if all of the contributing forces are known. Although the organism-environment system is at least as complex as this example, it is not hopelessly so because predicting the exact outcome of each interface is not necessary. What is necessary is to determine which interfaces of environmental and organic variables result in mishaps. One method of identifying these critical interfaces is to retrospectively analyze past mishaps. By determining what combination of environmental and organic variables have historically resulted in mishaps, perhaps we can modify these variables or avoid their interface to make their conjunction less mutually destructive. Identifying these historically critical interfaces will be the task of this study.

METHOD

The method used approximates that used in a study by Mr. Roger Crewse, Chief of the Reports and Analysis Division, AFISC (3). His study attempted to discover a pattern of why accidents happened as opposed to what happened. (Safety Investigation Boards essentially provide us with the "what.") By a process involving the study of past mishaps, categorizing, quantifying, and analyzing, he identified 17 "second-level causes" of mishaps. This study will borrow from that technique with some modifications.

Source of Data

Data were collected from mishaps occurring from 1 January 1977 through 30 June 1978. This period was selected for several reasons. First, it represents peacetime operations. Although published mishap rates remain relatively stable during combat operations, several factors introduced during wartime would only serve to further complicate the matter. Second, this period is fairly recent and consequently well within the period of rate-decrease stagnation, the period of prime concern. Last, all mishap reports in this period were available for study, whereas more recent reports were still being administratively processed. During this period, 139 Class A mishaps occurred, 77 of which were attributed to operator error. For the purpose of this study, operator error means that the pilot flying the aircraft at the time of the mishap was found to be, through act or omission, at least a contributing factor in the mishap. Three mishaps were excluded. One was a VC-131 whose gear collapsed during engine start. Although operator error was a factor, this was a ground mishap for all practical purposes. Even though "intent to fly" was demonstrated, this mishap was atypical of the other 76 to be considered. The two other excluded mishaps, a U-2 and an EB-57, lacked sufficient information to determine causal factors.

Procedure

The mishaps were divided by type into two major categories: "Collision with Ground/Water/Other Aircraft" and "Loss of Control." This represents a condensing of the 14 types assigned by AFISC/SER for computer coding and the five types used in Mr. Crewse's study (3). The distinction between these two categories is a fine one since ultimately all aircraft collided with the ground or water. The critical difference between the two is that in "collision" mishaps the proximity to an object (ground, water, or other aircraft) was hazardous to flight and had to be considered as an environmental factor by the pilot. In "loss of control" mishaps, the pilot exceeded the design limitations of the aircraft or of himself. Categorizing the confluence of the two (exceeding design limitations while attempting to avoid the ground/water/other aircraft) was decided individually, based on the judgment of whether proximity to a hazard was attended to prior to the point that recovery was impossible. Thus an aircraft that stalls and crashes in the recovery phase of a high-angle bombing pass is considered a "collision with the ground" since the loss of control was secondary to inadequate attention to the proximity of the ground before recovery became impossible. "Collision" mishaps accounted for 51% of the total considered, and "loss of control" for 49%. Each of these categories was further divided by type aircraft: attack, fighter, observation, trainer, cargo/bomber, and helicopter. The two major categories with their subcategories were arranged horizontally on a data-collection matrix. The vertical axis consisted of 34 major variables that described the contributing factors at the time of mishap.

These 34 major variables were derived from four sources. The first source was a study conducted by the U.S. Army Agency for Aviation Safety (USAAAVS) in 1973 (2). That study isolated nine factors which accounted for 96% of the Army's pilot-error accidents over a 4-year period. Eight of these factors, or variations thereof, were used as variables in this study. The second source for variables was the AF Form 711gA, a standard form used by the flight surgeon member of Safety Investigation Boards to identify psychophysiological and environmental causal factors of mishaps. Of the 91 factors on this form, 54 were incorporated in the major variables or their components in this study. The third source for variables was the 17 second-level causes identified in the study by Mr. Crewse (3). All of these are included to some extent in this study; however, the terms used to identify the second-level causes have been altered due to definition overlap and to accommodate the environmental/organic division of the variables as described below. The last source of variables was derived from my observations during 11 years of operational experience.

The 34 major variables selected were divided into two categories--12 attributable to the environment and 22 to the organism (operator). This division is based on the previously discussed assumption that each category contributes, to a certain degree, to each mishap. The environmental variables were further broken down into 1) physical factors--variables that address climatology and physical limitations imposed by equipment, 2) system factors--variables that address the degree to which the operator was prepared by the system to perform the mishap task, and 3) task-descriptive factors--variables that specify the activity engaged in at the time of the mishap. The operator variables were broken down into 1) physical/physiological/pathological factors--variables that address limiting physical conditions, physiological states, and skill level of the operator, and 2) psychological/psychosocial factors--variables that address limiting perceptual sets, habit patterns, or attitudes of the operator. In the interest of maintaining objectivity while studying the mishaps and to avoid inconsistency, each variable was carefully defined.

Major Variables and Their Components

Environmental Variables Defined

Physical Factors:

1. Weather-- Conditions at the time of mishap.

a. Climatic Conditions--Cloud cover, winds, temperature, or pressure altitude that impaired the performance of the operator, impaired the performance of the aircraft, or dictated the route of flight which ended in mishap.

b. Time of Day

(1) Daylight--Between 1/2 hour after official sunrise and 1/2 hour before official sunset.

(2) Darkness--Between 1/2 hour after official sunset and 1/2 hour before official sunrise.

(3) Transition--The two 1-hour periods of dawn and dusk, before daylight and darkness respectively.

2. Equipment Failure--Malfunction of equipment normally used in some phase of mission completion. Although the malfunction may not have incapacitated the aircraft, it may have contributed to the difficulty, complexity, or multiplicity of tasks.

a. Aircraft--A component internal to the aircraft malfunctioned.

b. Support--A component external to the aircraft, which provided essential support, malfunctioned; for example, ground radar, ground radios, runway lights.

3. Equipment Design Deficiencies--Deficiencies or shortcomings in the design of equipment normally used in some phase of mission completion, which contributed to the difficulty, complexity, or multiplicity of tasks.

a. Aircraft--Deficiencies in aircraft component design.

b. Support--Deficiencies in support equipment design.

4. Equipment Shortages--Shortages in equipment normally used in some phase of mission completion and whose absence may have contributed to the difficulty, complexity, or multiplicity of tasks.

a. Aircraft--Shortages in aircraft components.

b. Support--Shortages in support equipment.

System Factors:

5. Training--This variable addresses the quality, quantity, and timeliness of the training provided by the system to prepare the operator to complete the task being performed at the time of the mishap, assuming it was an authorized task.

a. Event Proficiency--The degree to which current training and practice were provided. Nonproficient is defined as: 1) The operator had never performed the task before, or 2) he had not performed it recently (within 8 weeks), or 3) he performed it recently for the first time (3).

b. Procedure/Technique Inadequacy--Established procedures and techniques inadequate to prepare the pilot to safely perform the task. This also refers to the qualifications of the instructor--was he skilled at instructing or merely skilled at flying?

6. Special Mission--A mission designated or inferred to be either a measure of overall capability or singularly urgent.

a. Actual Special Mission--A mission that measures overall capability or is singularly urgent, such as Search and Rescue, MEDEVAC, HURREVAC, or Emergency Resupply.

b. Perceived Special Mission--A mission that is merely perceived to be a measure of overall capability or to be singularly urgent, such as an operational exercise, an ORI, a checkride, or an aerial demonstration.

7. Supervision--The extent to which supervisors at all levels, by commission or omission, contributed to the conditions precipitating the mishap.

a. Command Control--The orderly distribution of authority and responsibility designed to systematically accomplish a general or a specific task, and the continuous-feedback-loop communications network connecting all levels of command so that decisions can be made, efforts coordinated, and discipline maintained. This definition covers the broad spectrum from Department of Defense policy to crew coordination.

b. Supervisory Pressure--Stated or implied expectation of conformity to a supervisor's priorities, whether they be appropriate or misplaced, based on a stated or implied threat of adverse effect on the subordinate's career.

c. Double Standard--Stated or implied condoning of violations of established procedure in the interest of mission accomplishment or an arbitrary perception that the rules do not apply.

d. Briefings--A premission meeting of crewmembers and immediate supervisors, held to outline, plan, and coordinate specific mission objectives, procedures, and contingencies.

8. Morale--The overall spirit of members of the working environment. High morale is characterized by a spirit of cooperation, unity, and common purpose.

a. Job Security--Reasonable assurance that a person will retain his job if established standards are met.

b. Consistent Policy--Uniform application of rules, regulations, and policies to everyone.

c. Reinforcement--Conferring of appropriate and equitable rewards for performance at or above the standard, and appropriate and equitable penalties for performance below the standard.

d. Competition--Group rivalry within the framework of common ground rules oriented toward a goal commonly accepted as desirable but limited as to the number who can achieve it. (For the purpose of this study: Is the goal or are the rules consistent with safe mission accomplishment?)

9. System Overcommitment--Assignment of a task for which the operator is not prepared or which, in combination with other tasks, overtaxes his capacity.

a. Task Demands--Demands of a single task exceed the operator's limitations.

b. Multiple Tasks--Multiplicity of tasks exceeds the operator's limitations.

Task-Descriptive Factors:

10. Phase of Flight--The phase in which the mishap occurred.

a. Takeoff--From taking the active runway to flying over the field boundaries.

b. Climbout--From field boundaries to cruise altitude.

c. Enroute--From reaching cruise altitude to the area of planned activity or destination initial approach fix.

d. Range--Area of planned activity. This may be a controlled gunnery range, a military operating area, a warning area, or a designated refueling or low-level track. Generally it is an area for practicing mission-unique operations.

e. Descent--From initial approach fix to missed approach point.

f. Landing--From missed approach point to end of runway. A go-around mishap is included in the landing phase.

11. Mission Element--The activity engaged in at time of mishap.

a. SAM Break--A maneuver designed to defeat a surface-to-air missile.

b. Low-Level Navigation--Navigation leg below 5000' AGL.

c. Low-Level Maneuvering--Range-related operations below 5000' AGL.

d. Air-to-Ground Ordnance Delivery

e. Air-to-Air Engagement

(1) DACT--Dissimilar aircraft combat tactics.
(2) SACT--Similar aircraft combat tactics.

f. Acrobatics

(1) Confidence--Acrobatics designed to increase pilot skill.
(2) Demonstration--Acrobatics designed to demonstrate pilot skill and/or aircraft capabilities.

g. Formation

(1) Rejoin
(2) Maneuvering

h. Search and Rescue--Actual search for a downed aircraft.

i. Basic Aircraft Maneuvering--Flight activity common to all aircraft, such as takeoff, landing, or go-around.

12. Deployed--The mishap mission was launched from, and with planned return to, a station other than the base to which it was permanently assigned.

Operator Variables Defined

Physical/Physiological/Pathological Factors:

13. Preexisting Illness/Defect--Any illness or physical defect, existing prior to and at the time of the mishap, which may have impaired the operator's ability to perform the task or which may have resulted in preoccupation with the symptoms at an inappropriate time.

14. Nutritional State--The type or quantity of food or beverages consumed in the 12 hours prior to the mishap adversely affected the performance capability of the operator.

15. Drugs--Presence, at the time of the mishap, of any chemical compound introduced into the operator for medication, disease prevention, weight loss, or mood alteration.

16. Fatigue--Progressive decrement in performance efficiency due to prolonged activity, strenuous activity, or sleep deprivation. Activity may be physical or mental.

17. G.A.S.(General Adaptation Syndrome)--The heightened physiological state automatically assumed by the organism when faced with a crisis, to prepare for "fight or flight." This heightened physiological state may detract from rational processes and cause the operator to overreact, overcontrol, or overlook significant cues.

18. Situation Disorientation--Confusion as to relative environmental orientation as a result of inadequate sensory stimuli, incorrect interpretation of sensory stimuli due to limitations of sensory receptors, or absence of a general cognitive framework that realistically orients the operator within his environment.

19. Circadian Rhythm--The tendency for biological activities to occur at regular intervals over approximately a 24-hour period. Circadian rhythm is considered here in the broad sense as it applies to crossing three or more time zones, as opposed to activity that is merely outside the normal sleep-wake-eat cycle.

20. Age--Chronological age of the operator.

21. Task Proficiency--Relative skill level of the operator in the task he was performing when the mishap occurred. This variable addresses both competency and currency.

a. Total Flying Time--Total pilot time in all aircraft.

b. UE Time--Total pilot time in the type aircraft the mishap occurred in.

c. No Prior--The operator had never performed the task before.

d. No Recent Prior--The operator had performed the task before but not recently (within 8 weeks).

e. Recent but First--The operator had performed the task recently but for the first time (3).

22. Physical Condition--General physical condition of the operator: 1=good, 2=fair, or 3=poor.

Psychological/Psychosocial Factors:

23. Confidence--A perceptual set in which the operator is predisposed to think that he can perform a task with the tools available.

a. Confidence in Self

(1) Overconfidence--The operator is predisposed to think that he can successfully perform a task even though he has not successfully performed it in the past, has not successfully performed it recently, or has successfully performed it in the past but under different circumstances.

(2) Underconfidence--The operator is predisposed to think that he cannot successfully perform a task, even though he has performed it successfully and often in the recent past.

b. Confidence in Equipment

(1) Overconfidence--The operator is predisposed to think that his aircraft will perform a maneuver even though it has never been tried before or is clearly beyond design limitations, or some critical component is known to be malfunctioning.

(2) Underconfidence--The operator is predisposed to think that his aircraft cannot perform a maneuver even though it has in the past, the maneuver is within design limitations, and there are no known critical component malfunctions.

24. Self-Overcommitment--A course of action chosen by an operator that commits him to a task for which he is knowingly ill-prepared and that presses him or his aircraft beyond their limits.

a. Task Demands--Demands of a single task exceed the operator's or aircraft's capabilities.

b. Multiple Tasks--Demands of several tasks, taken together, exceed the operator's or aircraft's capabilities.

25. Habit Substitution--The tendency to resort to old response patterns as a substitute for appropriate responses which are not as familiar to the operator.

26. Decision Delay--A delay in the operator's commitment to a course of action even though sufficient information is available to make the correct decision. This represents an unresolved approach-avoidance conflict.

27. Concentration--Focusing attention on a specific task.

a. Channelized Attention--Focusing attention on a specific task at the expense of ignoring others of a higher or more immediate priority.

b. Distraction--Interruption of focus of attention on a specific task by the introduction of a non-task-related stimulus.

(1) Physical--Interruption by a non-task-related sensory stimulus.

(2) Mental--Interruption by a non-task-related mental process.

c. Inattention--Insufficient attention to environmental cues.

d. Habituation--Adaptation and subsequent inattention to environmental cues after prolonged exposure to them.

28. Personality Type--A general characterization of the disposition and temperament of the operator in terms of trait tendency.

a. Type A--Tends to be aggressive, schedule conscious, outgoing, always on the go, well-organized, and systematic in approach to obstacles. Sets high personal standards and expects the same of others.

b. Type B--Tends to be easygoing, not bound by rules or time schedules, has a live-and-let-live attitude, and has a flexible system of standards which is not imposed on others.

29. Judgment Error--With sufficient data available to choose the correct course of action, the operator nevertheless chose the wrong course.

30. Discipline Breakdown--Deviation from established, effective methods of orderly and systematic accomplishment of a task.

31. Internalized Unit Values--The operator has taken the values, motives, and prioritized goals of the unit as his own.

32. Weak Pilot--One who has consistently performed below the level of peers but above minimum standards.

33. Copilot Syndrome--The tendency for a person not directly responsible for task completion in a social milieu (crewmembers, other members of the flight, communication networks) to not perform to his optimum, based on the comforting premise that the one responsible has the situation well in hand and will take care of him.

34. Violation of Regulations--A violation of published directives, which contributed to the conditions precipitating the mishap.

Use of Variables

A qualifying statement must be made concerning the value, utility, and universality of these definitions. They cannot be considered to be mutually exclusive nor to form a taxonomy of all variables contributing to mishap potential. Such an all-inclusive taxonomy does not exist, nor is it likely that it ever will. Because of the complexity of man's interface with his environment and the limitations of the language due to imprecise and dual-meaning terms, exact and universally accepted definitions to describe the variables are not possible. However, workable definitions to describe these phenomena are possible. Definitions of terms have been conspicuously lacking in previous efforts to isolate mishap variables, yet such definitions are essential for any orderly, systematic classification. Even a less than perfect definition is better than none at all, as long as it addresses the major operating factors of the phenomena and is applied consistently. Such is the nature of these definitions. The meaning of the terms used in this study is limited to the definitions presented here; to infer further meaning could result in unwarranted conclusions.

These 97 major variables and components were arranged on the vertical axis to complete the data-collection matrix. Next began the arduous process of categorizing and studying the 76 mishap reports. Based on categories defined previously, the 76 mishaps were classified in the following manner:

TABLE 1. CLASSIFICATION OF AIRCRAFT CLASS A MISHAPS

	Collision	Control loss
Attack	6	2
Fighter	25	16
Observation	4	4
Trainer	1	8
Cargo/Bomber	2	3
Helicopter	1	4

Each mishap was then carefully studied to determine which variables, as defined, existed at the time of the mishap. A mark was placed next to each variable present in each mishap. These determinations did not necessarily represent board findings.

RESULTS

Four of the major variables and their components were eliminated from consideration. Physical condition was eliminated because virtually all reports indicated that the mishap pilot was in excellent physical condition prior to the mishap. One had a heart attack in flight, but even he didn't have a history of heart disease. Although it is questionable that all pilots were, in fact, in excellent physical condition, that is what the reports indicated. Consequently this variable, which did not vary, was considered meaningless as a causative factor. Morale, Personality Type, and Internalized Unit Values were also eliminated as variables. Safety Investigation Boards simply did not address these topics in their reports, so the data were not available from that source. The following table lists the percentage of contributing-variable incidence by Total, Collision, and [illegible]s-of-Control mishaps. The sum

TABLE 2. INCIDENCE OF VARIABLES IN CLASS A MISHAPS

Variable	% Total	% Collision	% Control Loss
1. Weather			
a. Climatic Conditions	34	36	32
b. Time of Day			
(1) Daylight	83	74	92
(2) Darkness	16	26	5
(3) Transition	1	0	3
2. Equipment Failure	21	15	27
a. Aircraft	17	10	24
b. Support	5	5	5
3. Equipment Design	20	21	20
a. Aircraft	12	13	11
b. Support	8	8	8
4. Equipment Shortages	3	3	3
a. Aircraft	0	0	0
b. Support	3	3	3
5. Training	53	54	51
a. Event Proficiency	27	28	27
b. Procedure/Technique Inadequacy	38	38	38
6. Special Mission	38	44	32
a. Actual	2	0	5
b. Perceived	36	44	27
7. Supervision	46	51	41
a. Command Control	37	38	35
b. Supervisory Pressure	4	5	3

TABLE 2. (Continued)

Variable	% Total	% Collision	% Control Loss
c. Double Standard	13	15	11
d. Briefings	20	28	11
8. System Overcommitment	21	28	14
a. Task Demands	17	23	11
b. Multiple Tasks	7	10	3
9. Phase of Flight			
a. Takeoff	0	0	0
b. Climbout	5	8	3
c. Enroute	12	13	11
d. Range	62	72	51
e. Descent	8	0	16
f. Landing	13	3	20
10. Mission Element			
a. SAM Break	1	0	3
b. L/L Nav	13	21	5
c. L/L Maneuver	28	46	8
d. Air-to-Grnd Ord	17	26	8
e. Air-to-Air Eng	18	23	14
(1) DACT	12	15	8
(2) SACT	8	8	8
f. Acrobatics	9	5	14
(1) Confidence	7	0	14
(2) Demonstration	2	5	0
g. Formation	34	44	24
(1) Rejoin	9	13	5
(2) Maneuvering	25	31	20

TABLE 2. (Continued)

Variable	% Total	% Collision	% Control Loss
h. Search and Rescue	3	0	5
i. Basic Acft Maneuvers	26	13	41
11. Deployed	24	33	8
12. Preexisting Illness/Defect	14	21	8
13. Nutritional State	4	3	5
14. Drugs	3	5	0
15. Fatigue	22	28	16
16. G.A.S.	28	28	30
17. Situation Disorientation	47	64	30
18. Circadian Rhythm	4	0	8
19. Age (Avg)	31[a]	31[b]	31[c]
20. Task Proficiency	42	36	47
a. Total Time (Avg)	1892[d]	1961[e]	1823[f]
b. UE Time (Avg)	646[g]	668[h]	624[i]
c. No Prior	20	13	27
d. No Recent Prior	16	15	16
e. Recent but First	7	5	8
21. Confidence	28	28	27
a. Self	26	26	27
(1) Over	24	26	22
(2) Under	4	0	8
b. Equipment	1	3	0
(1) Over	1	3	0
(2) Under	0	0	0

[a]Fig. 2; [b]Fig. 3; [c]Fig. 4; [d]Fig. 5; [e]Fig. 6; [f]Fig. 7; [g]Fig. 8; [h]Fig. 9; [i]Fig 10.

TABLE 2. (Continued)

Variable	% Total	% Collision	% Control Loss
22. Self-Overcommitment	36	44	27
a. Task Demands	42	41	44
b. Multiple Tasks	4	5	3
23. Habit Substitution	25	18	32
24. Decision Delay	12	13	11
25. Concentration	84	90	78
a. Channelized Attn	42	36	48
b. Distraction	37	38	35
(1) Physical	17	18	16
(2) Mental	24	23	24
c. Inattention	28	26	30
d. Habituation	4	3	5
26. Judgment Error	63	72	54
27. Discipline Breakdown	28	41	8
28. Weak Pilot	15	13	16
29. Copilot Syndrome	17	13	22
30. Violation of Regs	26	36	16

of subelements may exceed the total in that variable due to co-occurrence of the subelements in some mishaps.

Although the average age, total time, and UE time are listed in the table, these do not represent meaningful information. The mode, or the range which occurred most frequently, would be more informative, and histograms of these data are contained in Figures 2-10. Variables identified in less than 5% of the mishaps were eliminated from further statistical analysis. These included Transition (Dawn/Dusk), Equipment Shortage, Actual Special Missions, Supervisor Pressure, Takeoff, SAM Break, Acrobatic Demonstrations, SAR, Nutritional State, Drugs, Circadian Rhythm, Underconfidence in Self, Confidence in Equipment, Self-Overcommitment by Multiple Tasks, and Habituation. The remaining 60 variables were then analyzed to determine: (1) significant incidence of variables as they occurred individually, and (2) significant coincidence of variables as they occurred with other variables.

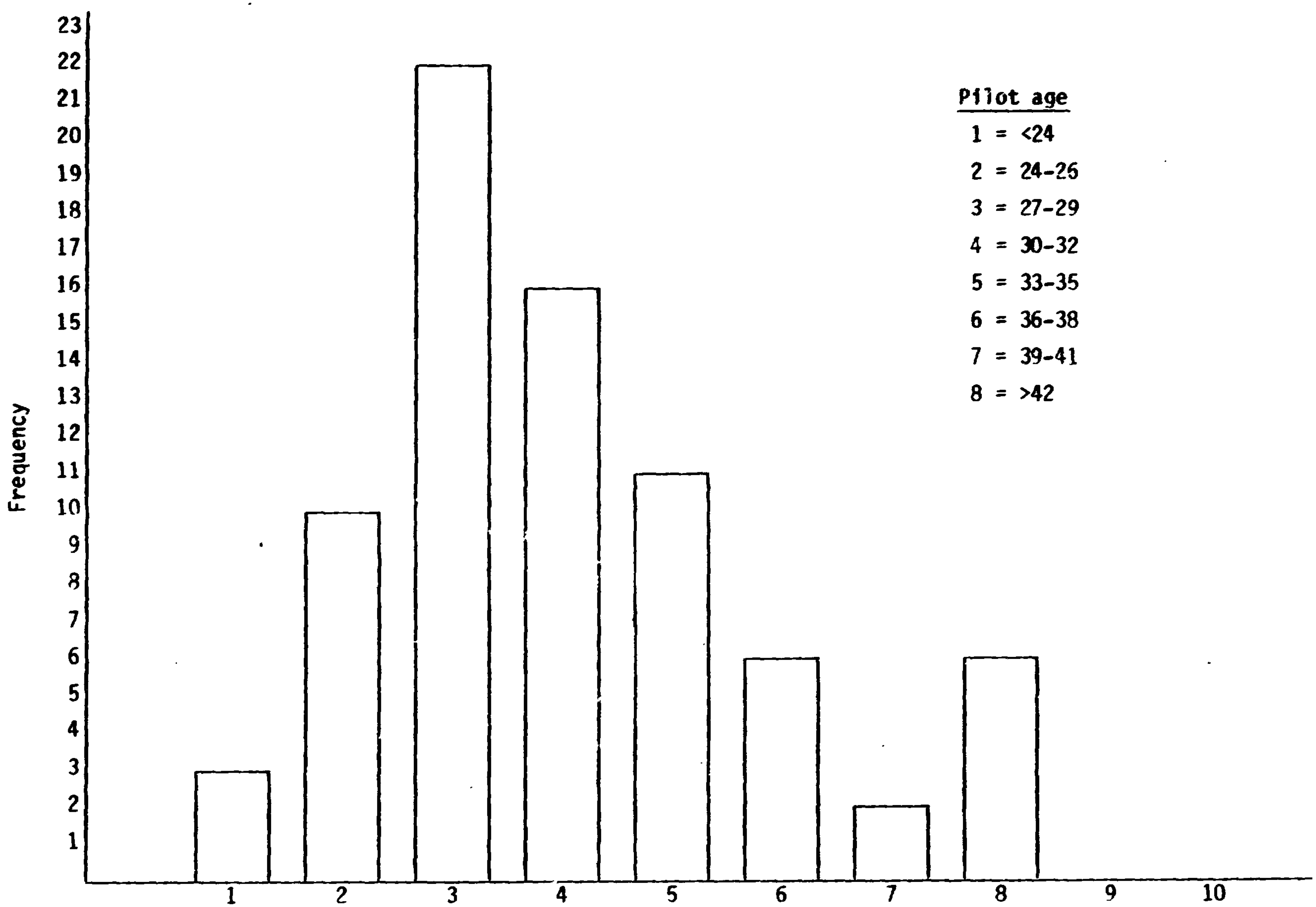

Figure 2. Correlation of pilot age and USAF aircraft mishaps (overall).

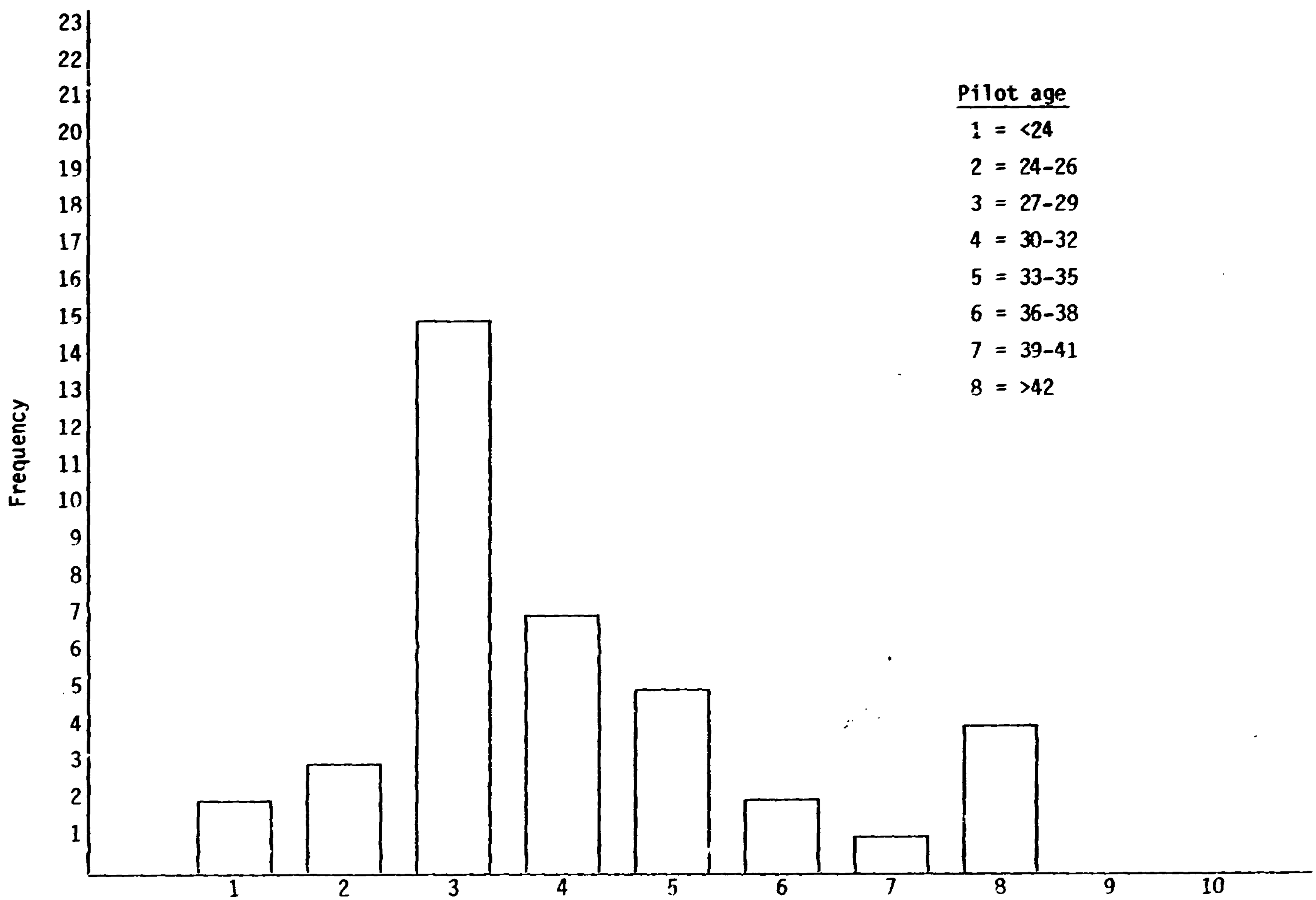

Figure 3. Correlation of pilot age and aircraft collision mishaps.

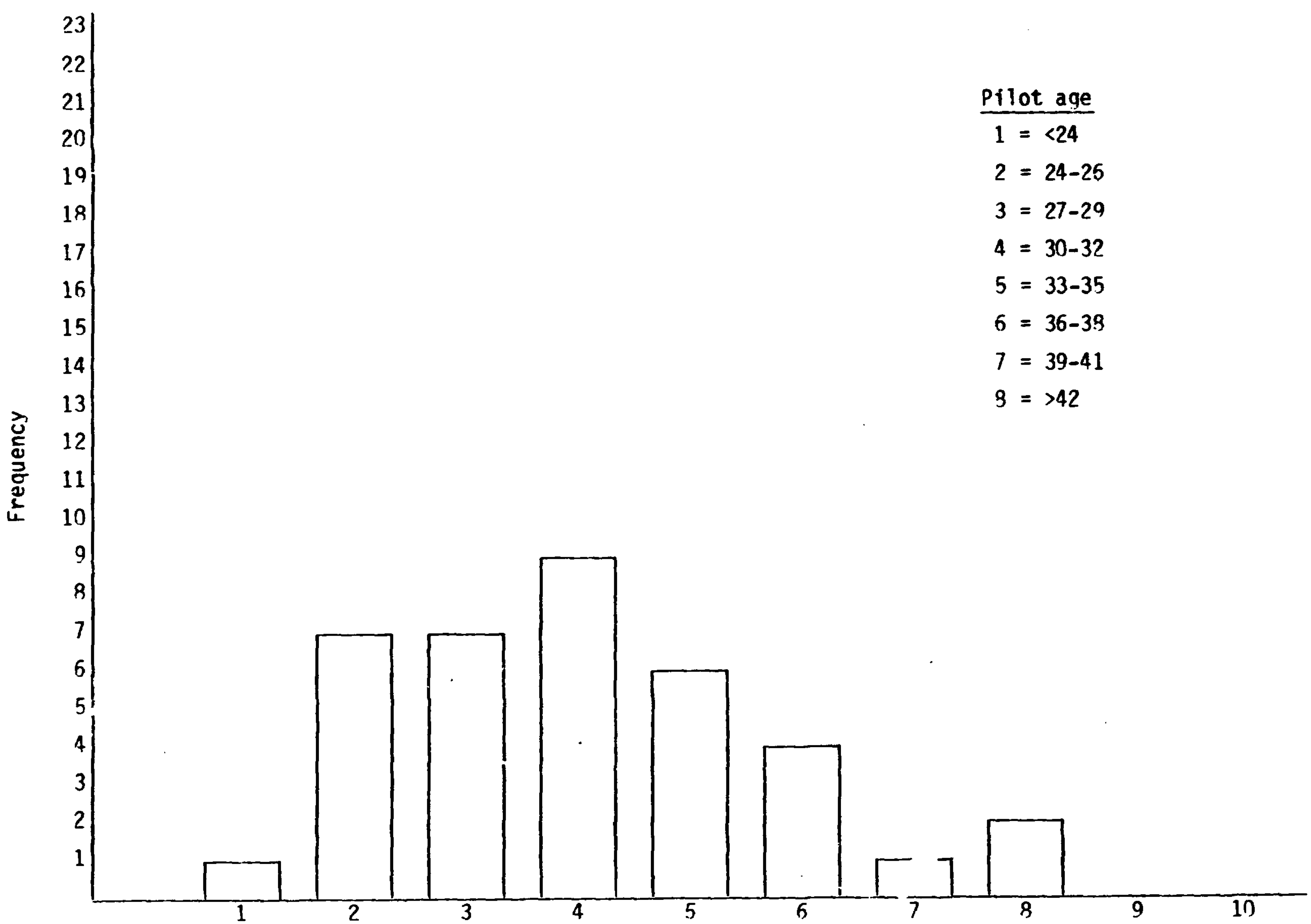

Figure 4. Correlation of pilot age and loss-of-control mishaps.

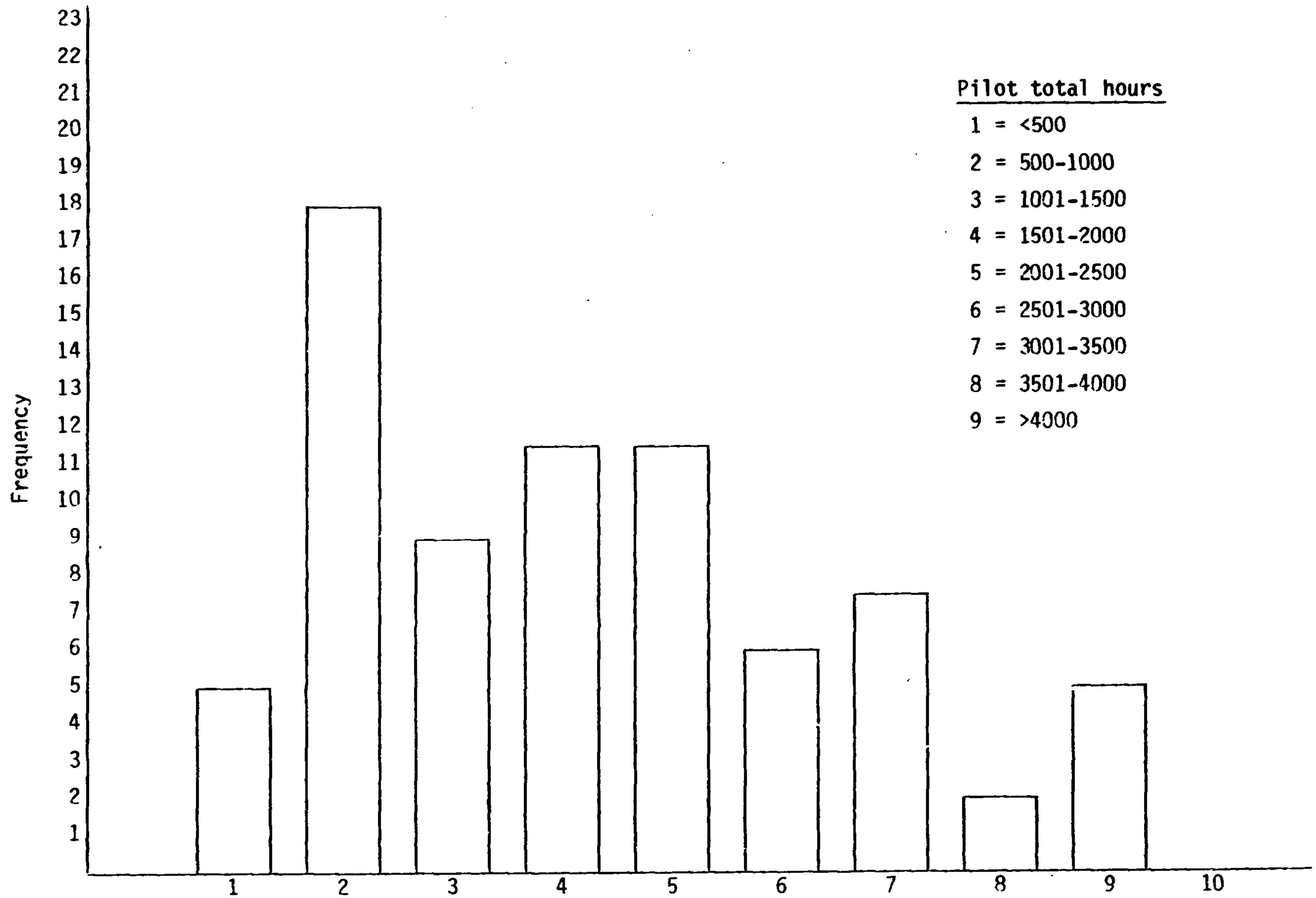

Figure 5. Correlation of total pilot time with USAF aircraft mishaps.

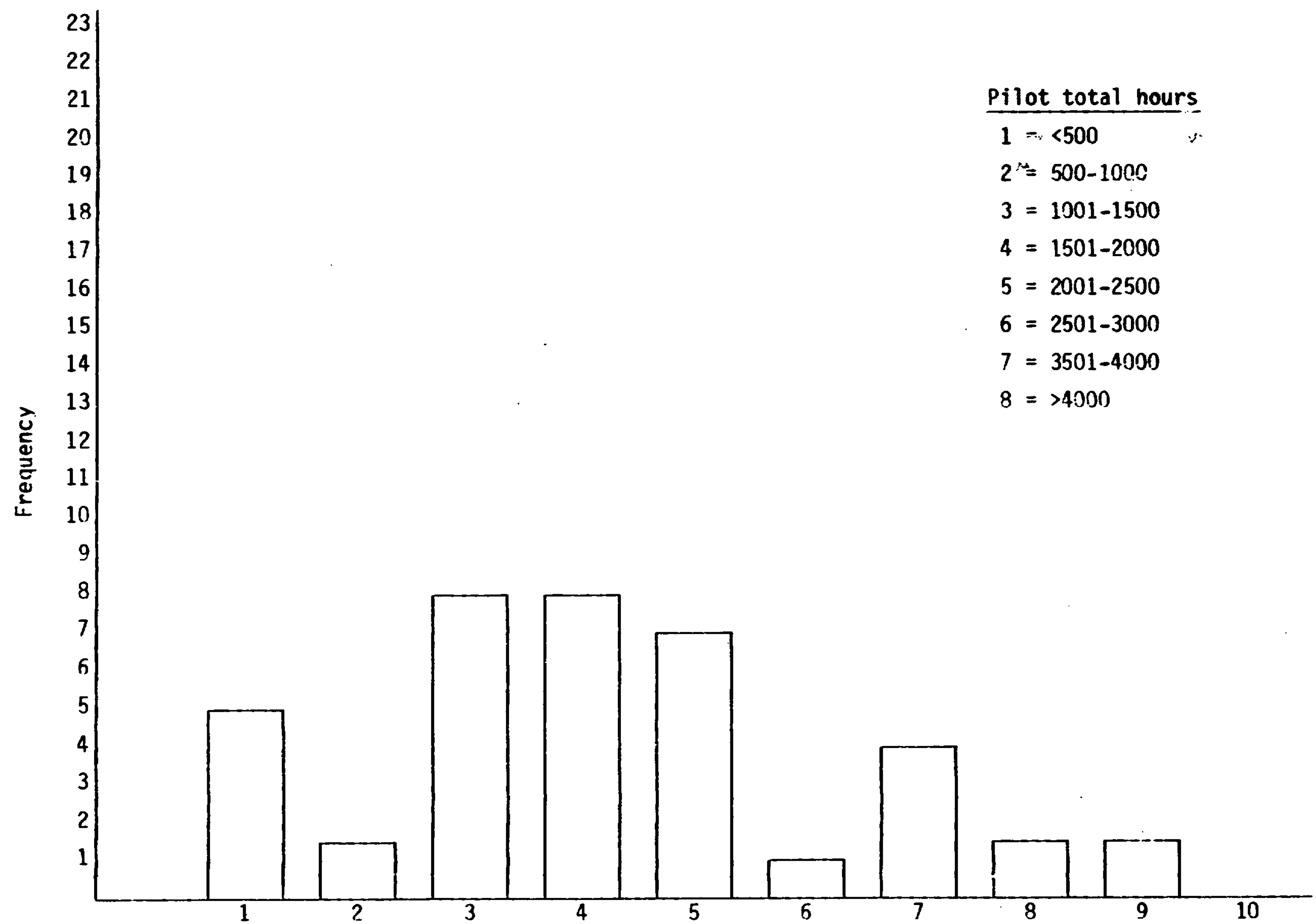

Figure 6. Correlation of total pilot time with aircraft collision mishaps.

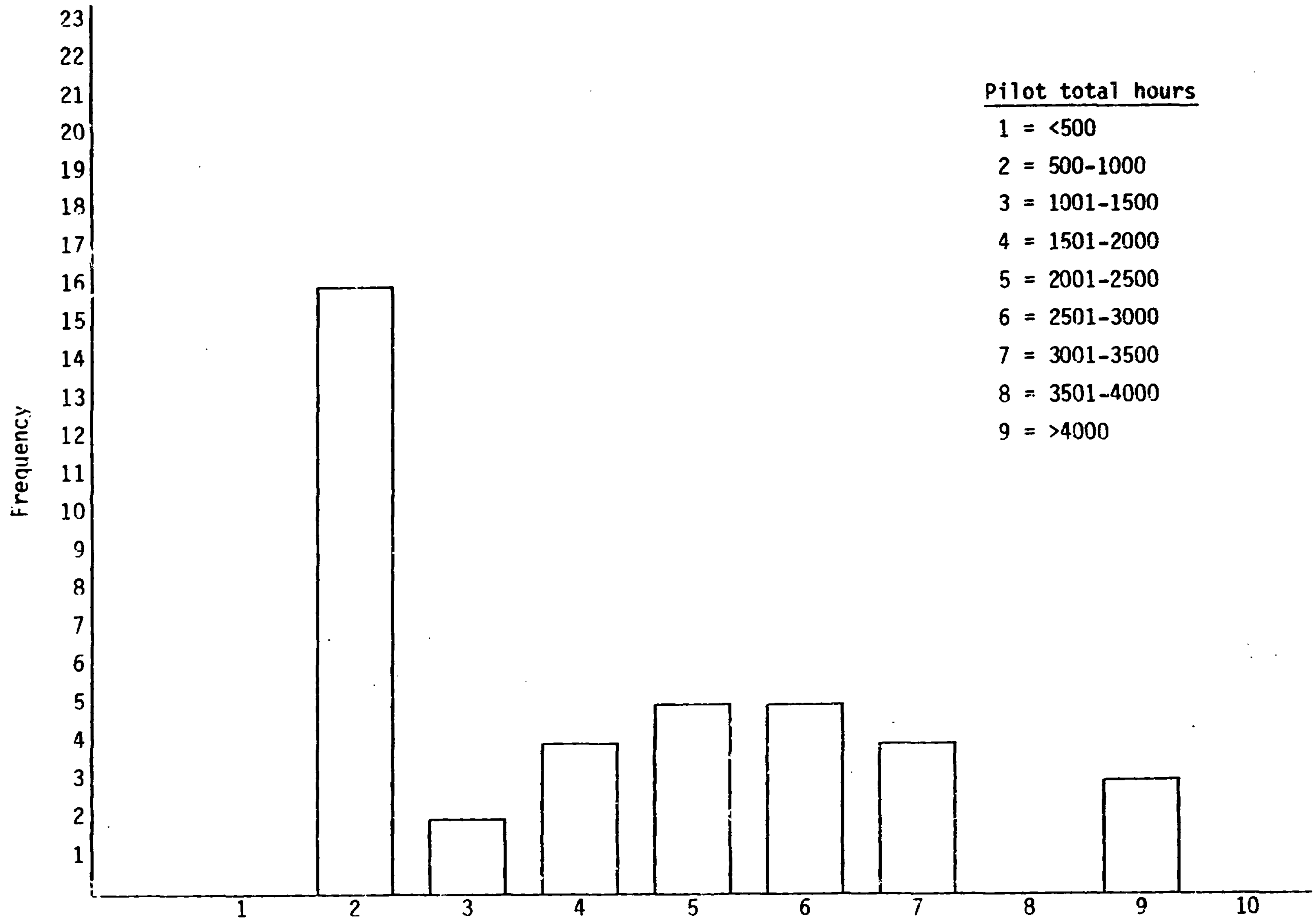

Figure 7. Correlation of total pilot time with loss-of-control mishaps.

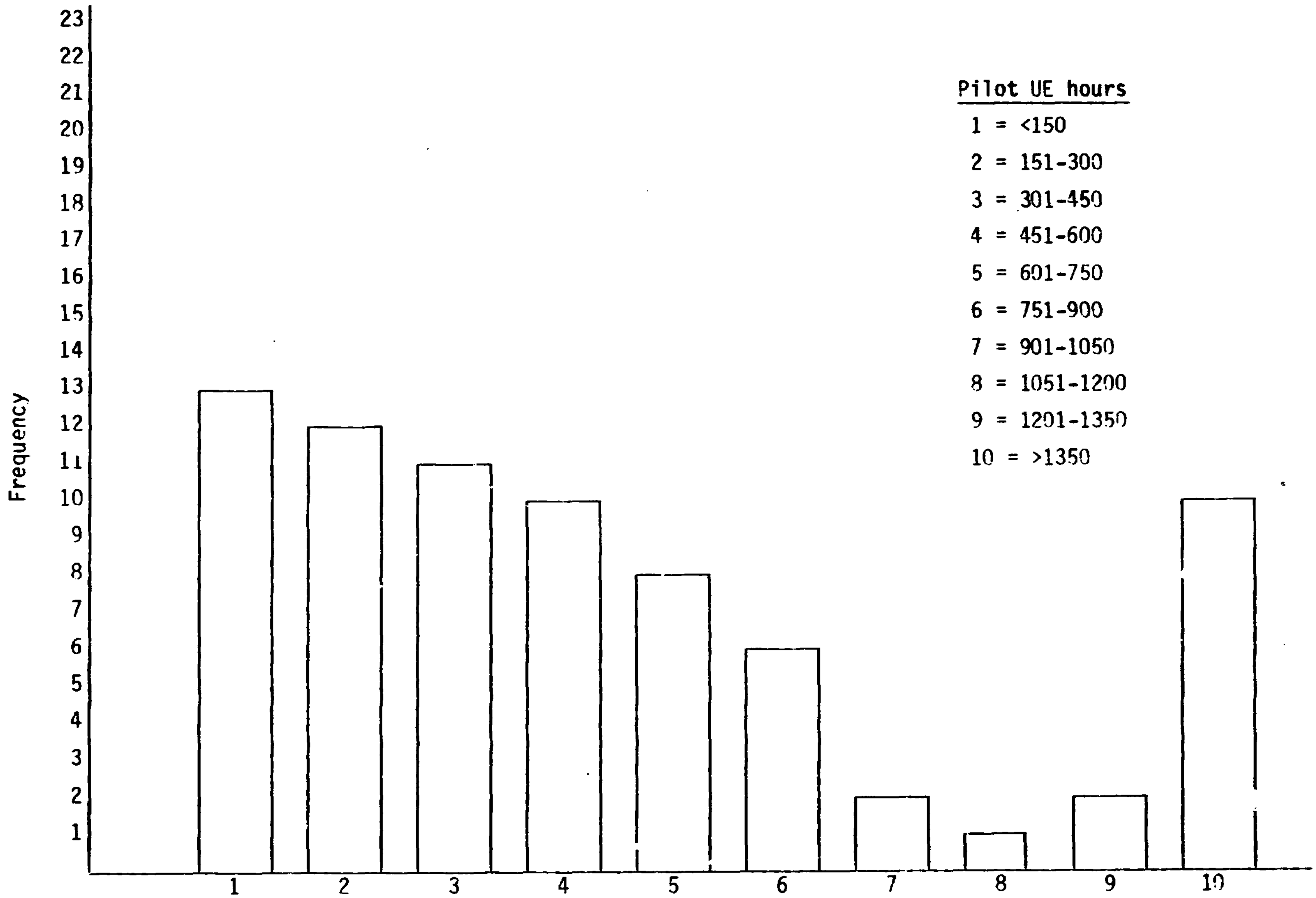

Figure 8. Correlation of pilot UE time and USAF aircraft mishaps.

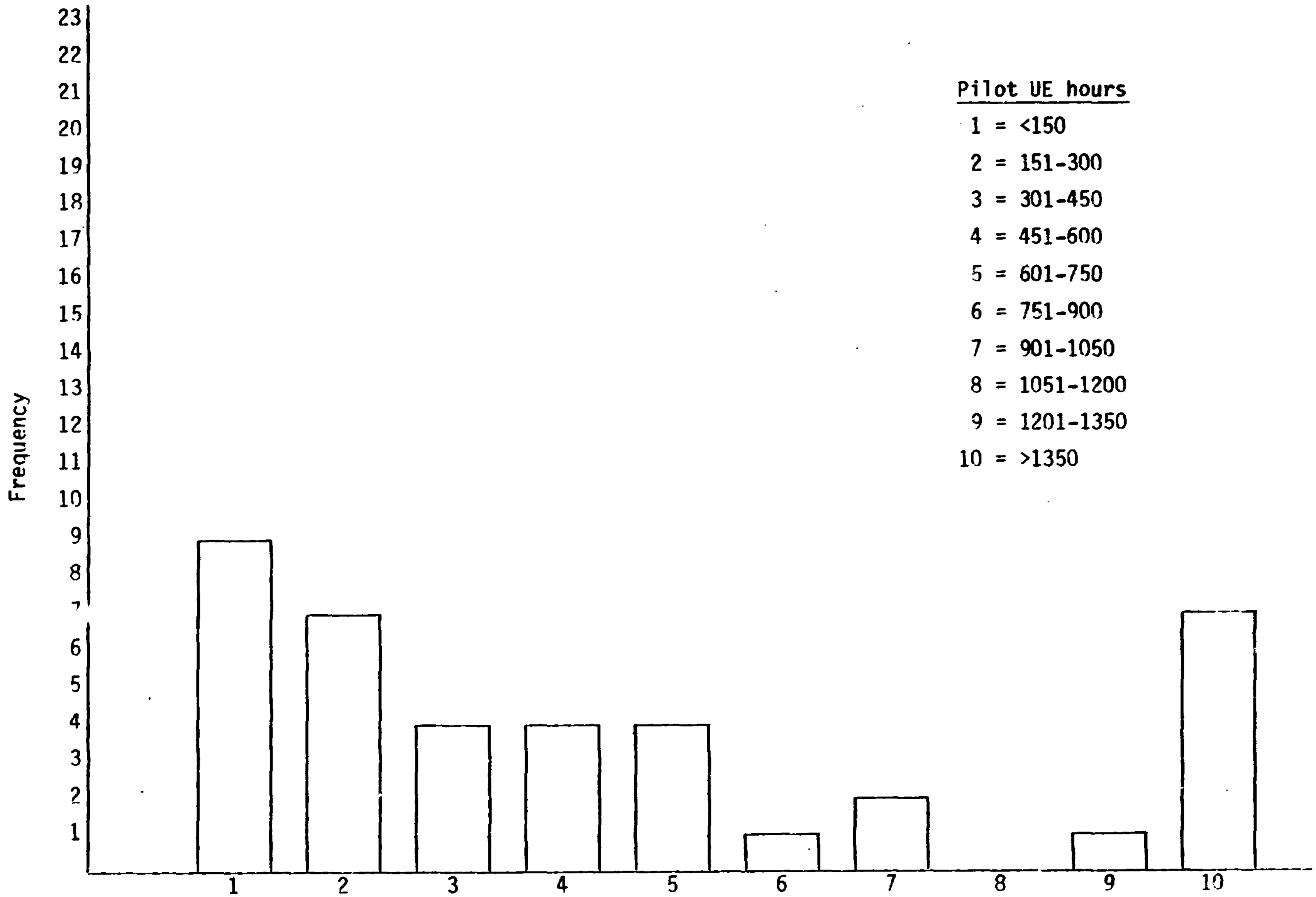

Figure 9. Correlation of pilot UE time and aircraft collision mishaps.

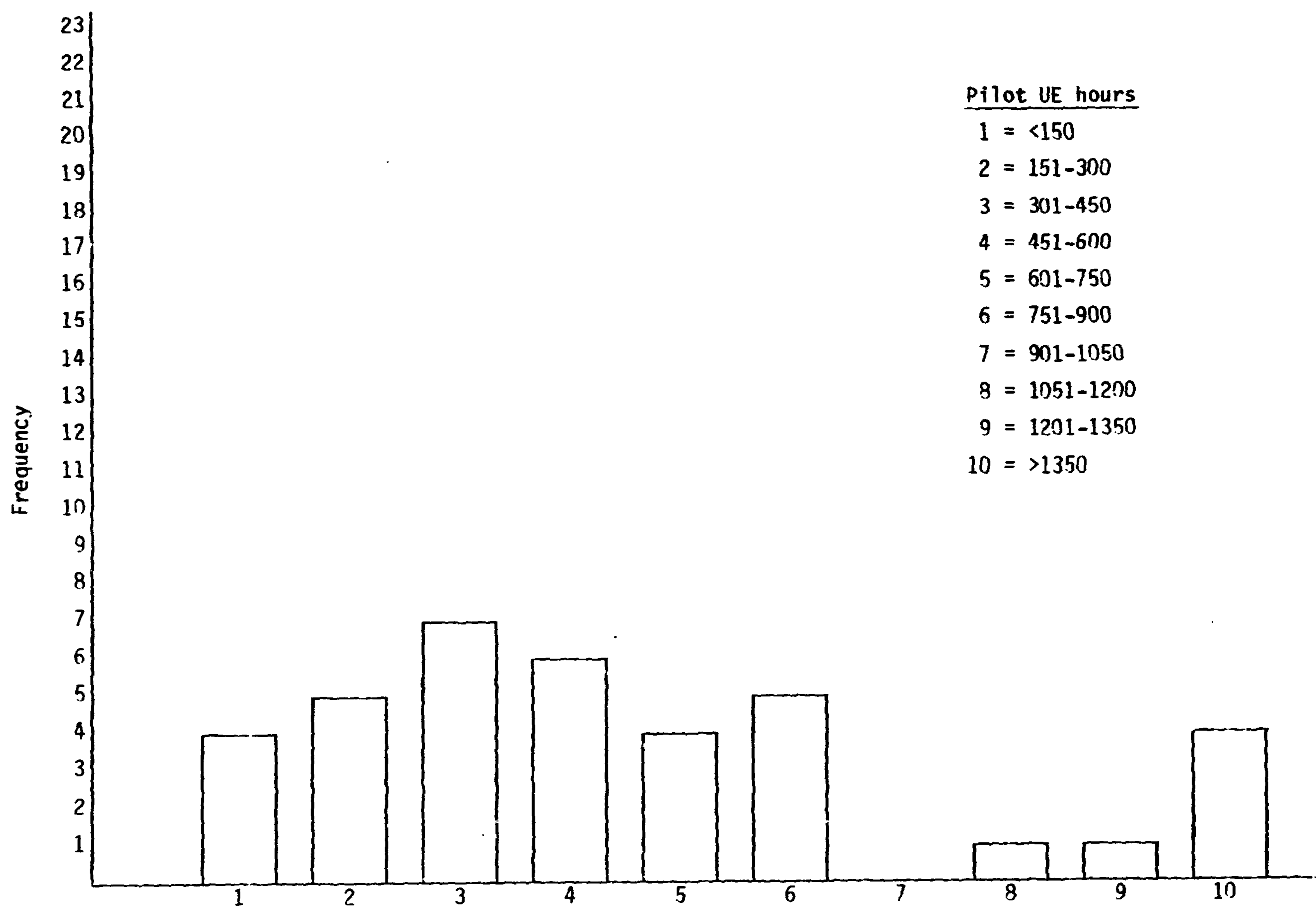

Figure 10. Correlation of pilot UE time and loss-of-control mishaps.

ANALYSIS

A simple analysis of the data summary (Table 2 minus variables < 5%) reveals a gross scenario of a typical mishap. On a daylight (74%) formation (44%) sortie, which is perceived to be a special (44%) range mission (72%) and in marginal weather (36%), a 29-year-old pilot with 1500 hours total flying time, 150 of which is in the aircraft he is flying, makes an error in judgment (72%) which is not corrected by adequate supervision (51%). For motives unknown, the pilot overcommits himself (44%) to a task, the demands of which exceed his present ability in that he has not attempted it before or recently (36%) and for which existing procedures are not adequate (38%). While attempting to perform a low-level maneuver (46%), he fails to concentrate on the appropriate cues (90%), experiences situational disorientation (64%), and collides with ground (51%). Although this is an interesting story and, in fact, contains the variables that occurred most often, no meaningful conclusions can be drawn regarding the critical interfaces of the environmental and organic variables. Such conclusions must come from a comparison of interacting variables.

Data analysis was accomplished by digital computer. A contingency table was constructed for each pair of variables (say "A" and "B"), showing the frequency with which A and B occurred together, neither occurred, A occurred and B was absent, or B occurred and A was absent. A chi-square statistic was then computed to test for significant association between the two variables. Simply stated, the test addresses the question "Does A occur more frequently when B is present than when B is not present?" It is important to note that a significant result does not imply a causal relationship, but merely an association, between the two variables. So, although we cannot say that the occurrence of B caused the occurrence of A, we can say that the interface of the two occurs more often than one would expect by chance occurrence.

Knowing the combinations of variables which occur more frequently than expected in mishaps would be invaluable in determining where to focus our efforts to minimize their effects. These combinations, or critical interfaces, are listed in Table 3. The variable in the leftmost column was found to significantly co-occur with each of the variables in the other three columns at the .05, .01, and .001 significance levels respectively. (The significance level represents the probability that the observed result happened by chance when no real association was present.) This analysis was not performed by mishap type nor aircraft type, because the sample size of each precluded reliable results. Variables not found to have significant interfaces were not listed on Table 3.

Data not yet considered are those of age, total time, and UE time (Figs. 2-10). No extraordinary revelations are apparent here. Total time, UE time, and age of pilots in relation to mishap occurrence seem to reflect the overall composition of our pilot force by the type aircraft flown, age, and subsequent experience level. The exception to this is the relatively high number of mishaps of pilots over 42 years of age with over 4,000 hours total time and over 1,350 hours UE time. In general, age, despite its concomitant experience, appears to become a critical factor only at the high end when the organism is less able to meet the psychomotor demands of the environment. The exception to this is UE time (Fig. 8). Clearly, low experience in an aircraft increases

TABLE 3. CRITICAL INTERFACES

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
1. Weather (climatic conditions)	Command control, climbout, landing, judgment error		
2. Darkness	Support-equipment failure, support-equipment design, self-overcommitment, low-level navigation, fatigue, situation disorientation, no recent prior experience, distraction	Support-equipment design, fatigue, situation disorientation	Fatigue, situation disorientation
3. Equipment failure	Darkness, descent, distraction, copilot syndrome	Descent	Descent
4. Equipment design	Darkness, DACT, situation disorientation, distraction, copilot syndrome		
5. Event proficiency	Air-ground ordnance delivery, command control, self-overcommitment (task demands), no recent prior experience, no prior experience	Air-gnd ordnance delivery, self-overcommitment (task demands), no recent prior experience, no prior experience	Air-gnd ordnance delivery, self-overcommitment (task demands), no prior experience
6. Procedure inadequacy	DACT, situation disorientation, distraction, acft-equipment design	DACT, acft-equipment design	

TABLE 3. (Continued)

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
7. Special mission	Range, deployed, self-overcommitment, mental distraction, discipline breakdown	Deployed, mental distraction	Deployed
8. Command control	Weather, system overcommitment (task demands), low-level nav, support-equipment failure, briefings, fatigue	Support-equipment failure, fatigue, briefings	Briefings
9. Double standard	Briefings, SACT, self-overconfidence, habit substitution, decision delay, judgment error	SACT	SACT
10. Briefings	Double standard, self-overcommitment, low-level nav, no recent experience, discipline breakdown, regs violated, command control	Command control, low-level nav	Command control, low-level nav
11. System overcommitment (task demands)	Command control, air-gnd ordnance delivery, event proficiency, no prior experience, range	Event proficiency, command control, air-gnd ordnance delivery, no prior experience	Event proficiency, air-gnd ordnance delivery
12. System overcommitment (multiple tasks)	Acft-equipment design, briefings, air-gnd ordnance delivery, fatigue, range	Air-gnd ordnance delivery, fatigue, range	Air-gnd ordnance delivery, range

TABLE 3. (Continued)

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
13. Climbout	Weather, acft-equipment failure, distraction (physical)		
14. Range	Special mission, system overcommitment (task demands), self-overcommitment	Self-overcommitment	
15. Descent	Aircraft- & support-equipment failure, copilot syndrome	Aircraft- & support-equipment failure, copilot syndrome	Support-equipment failure
16. Landing	Weather, support-equipment design		
17. Low-level navigation	Darkness, command control, briefings, fatigue, distraction (mental), regs violated	Fatigue, briefings	Briefings
18. Low-level maneuvers	Inattention		
19. Air-gnd ordnance delivery	Event proficiency, self-overcommitment, situation disorientation, no prior experience, inattention		
20. DACT	Acft-equipment design, procedure inadequacy, situation disorientation, channelized attention	Channelized attention, procedure inadequacy	
21. SACT	Double standard, fatigue, self-overconfidence, discipline breakdown, regs violated	Double standard, self-overconfidence	Double standard, self-overconfidence

TABLE 3. (Continued)

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
22. Acrobatics (aerial demonstration)	Special mission, recent but first		
23. Basic air maneuver	Weather, acft-equipment failure, support-equipment design, command control, mental distraction	Acft-equipment failure, support-equipment design, mental distraction	
24. Deployed	Special mission, no prior experience	Special mission	Special mission
25. Fatigue	Darkness, support-equipment design, command control, self-overcommitment (mulitiple tasks), low-level nav, SACT, mental distraction	Darkness, command control, self-overcommitment (multiple tasks), low-level nav	Darkness
26. Situation disorientation	Darkness, support-equipment design, procedure inadequacy, air-ground ordnance delivery, DACT, channelized attention	Darkness, support-equipment design, procedure inadequacy	Darkness
27. No prior experience	Air-ground ordnance delivery, deployed, copilot syndrome		
28. No recent prior experience	Darkness, briefings		
29. Recent but first	Acrobatics		

TABLE 3. (Continued)

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
30. Self-overconfidence	Double standard, SACT, self-overcommitment, concentration, judgment error, discipline breakdown, regs violated	SACT, discipline breakdown, regs violated	SACT, discipline breakdown
31. Self-overcommitment	Special mission, range, task proficiency, decision delay, judgment error, discipline breakdown, weak pilot	Range, discipline breakdown, weak pilot, judgment error	Judgment error, discipline breakdown
32. Habit substitution	Double standard		
33. Decision delay	Double standard, self-overcommitment, judgment error		
34. Channelized attention	DACT, situation disorientation	DACT	
35. Distraction (physical)	Equipment failure & design, procedure inadequacy, climbout		
36. Distraction (mental)	Special mission, low-level nav, basic air maneuver, fatigue	Special mission	
37. Inattention	Low-level maneuver, air-ground ordnance delivery, copilot syndrome	Copilot syndrome	Copilot syndrome
38. Judgment error	Weather, double standard, task proficiency, self-overconfidence, decision delay, discipline breakdown, self-overcommitment	Self-overcommitment, discipline breakdown	Self-overcommitment

TABLE 3. (Continued)

VARIABLE	SIGNIFICANCE LEVEL .05	.01	.001
39. Discipline breakdown	Special mission, briefings, SACT, self-overconfidence, judgment error, weak pilot, regs violated	Self-overconfidence, self-overcommitment, judgment error, regs violated	Self-overconfidence, self-overcommitment, regs violated
40. Weak pilot	Self-overcommitment, discipline breakdown, regs violated	Self-overcommitment	
41. Regs violated	Briefings, low-level nav, SACT, self-overconfidence, discipline breakdown, weak pilot	Self-overconfidence, discipline breakdown	Discipline breakdown
42. Copilot syndrome	Support-equipment failure, acft-equipment design, descent, no prior experience, inattention	Descent, inattention	Inattention

the potential for mishap. These observations generally hold true when applied to collision versus control-loss mishaps as well. One notable difference between the two, for which there is no apparent explanation, is that pilots with a total time of 500-1000 hours had a much higher incidence of control-loss mishaps than collision mishaps (Figs. 6 and 7).

CONCLUSIONS AND DISCUSSION

We have identified four major environmental and four major organic variables that historically have been large players in mishaps. They are: Environment--Weather, Training Deficiencies, Supervisory Deficiencies, and Special Missions; and Organic--Situation Disorientation, Task Proficiency, Concentration Deficiencies, and Judgment Error. Their co-occurrence with other variables represents the major contributions to mishaps. We have also identified other critical interfaces that frequently result in mishaps (Table 3). During the study of each mishap, we noted whether the environment or the organism provided the most significant factors: 72% of the time, for both collision and control-loss mishaps, it was the organism; the other 28% of the time, the environment clearly provided the critical ingredient; i.e., the pilot was "set up." The inference here is that, even though an interface of environment and organism is required to precipitate a mishap, the organism more often provides the critical deficiency that results in mishap. As noted earlier, however, this critical deficiency is not necessarily an "error" on the operator's part.

The question remains, What part of the 72% represents a situation where the demands of the environment exceeded the capacity of the organism? This speaks to the problem of determining the varying capacity of individuals to cope with the environment, as well as determining to what extent, or at least acknowledging the fact, that we are increasing the physiological and psychological demands on the organism. These are significant and difficult questions to answer and are obviously beyond the scope of this study. What is within the scope of this study, as stated earlier, is a clearer definition of the problem on which to focus further efforts. On the basis of the framework established in this study, those efforts can take only three directions: (1) avoiding the critical interfaces of environment and organism, (2) decreasing the demands imposed by the environment on the organism, and (3) increasing the capacity of the organism to cope with the demands of the environment.

RECOMMENDATIONS

1. Avoiding critical interfaces could serve as an almost immediate although short-term fix in reducing aircraft mishaps. This approach assumes that neither the demands of the environment nor the capacity of the pilot to cope are changed. Its thrust would be to identify, by mission aircraft, the hazardous interfaces that are likely to occur. If these have been historically critical, then the unit commander must weigh the importance of the mission against the risk involved. If the mission must be flown, then the operations officer must assign a pilot who is most likely to meet the demands of the mission. For example, it would be sheer folly to schedule a pilot with low UE time and a history of concentration problems and poor judgment to a low-level range mission in marginal weather for the first time. Finally, the flight

crew should be briefed on the specific hazards of the mission, based on the known environment, and in what mode operators have historically failed to cope with it. This foreknowledge alone would go far in reducing mishap potential. Besides its relatively short implementation time, this approach eliminates the need for quantifiably predictable measures of individual psychological and physiological response modes, which are beyond our present capability anyway. The only requirement at unit level, other than minor procedural changes, is that training records be comprehensive and current and that managers know the strengths and weaknesses of their people. Such a system is currently in the offing and holds great promise for avoiding critical interfaces. This system, being developed by Mr. Roger Crewse, Chief, Reports & Analysis Division, Air Force Inspection and Safety Center, is based on assigning an index to the quantifiable aspects of mishap potential as determined by rates of these conditions in past mishaps. This is precisely the tool that unit commanders, operations officers, and schedulers need in order to determine the risk potential of individual missions. This system should be vigorously pursued and expeditiously implemented at unit level.

2. Reducing the demands of the environment is a somewhat broader, longer term, remedial approach, but at times not altogether practical. This study has concluded that a high potential for mishap exists during low-level range-type activities, particularly during perceived special missions such as exercises. Clearly the demands are great on the pilot in these situations. However, if this type activity is necessary to maintain a posture of reasonable defense preparedness (and necessity for this activity should be continuously reevaluated), then we should accept this risk as an inherent part of our defense program. What we don't have to accept are the environmental variables that have been identified in this study that can be changed.

a. Training--A close look should be taken at our continuation training program to determine if current procedures, techniques, and frequency of practice are sufficient to prepare the pilot to cope with the demands of the situations the system is placing him in. Inadequate procedures and lack of proficiency in the mishap event have consistently surfaced as significant environmental variables. A thorough evaluation of our notions of what skills pilots need to practice, how much practice they need, and what are the best procedures to safely perform a task, would go far toward at least identifying, if not reducing, self-imposed environmental limitations. The availability of defense dollars will have a large bearing on any changes in our training programs, but to be considered is the fact that accidents are very expensive and are getting more so.

b. Supervision--Another environmental variable conspicuous in mishaps was the degree and quality of supervision provided to the pilot, and by the pilot to the crew. The importance of a viable command-control system and the hazards of applying or condoning double standards were reaffirmed by the frequency of these variables in mishaps. Supervision implies leadership as well as management, and in the mishaps studied, the leadership aspect was sadly lacking. Perhaps more emphasis should be placed on leadership in preparing our younger officers for supervisory positions, and our more experienced officers for positions of command. This, in conjunction with clear lines of authority and responsibility, uniform compliance with established procedures, and uniform disciplinary standards, would reduce mishap potential.

These general areas can be pursued toward the end of reducing the level of demands with which pilots must cope. Avoiding critical interfaces and reducing environmental demands could modify existing short- and mid-term mishap prevention efforts.

3. Last, increasing the capacity of the operator to meet higher demands has the greatest potential for long-range mishap prevention, yet notably has received the least attention in the past. This should be a major thrust in human-factors research efforts, and some recommendations as to the initial direction of these efforts are offered.

a. Early in this study, we stated that one way to determine critical interfaces was by retrospective analysis (the method used here). Unfortunately, this method is only as good as the insight, training, and background of the safety investigation boards that provide the data. Some variables, particularly concerning "motivation" and "morale," were not addressed by boards at all. Other variables were identified in mishap reports infrequently merely because not many boards mentioned them, and only so much can be inferred from these reports. Furthermore, there is no reason to believe that variables identified by one board would be identified by another board since the terms are often not defined and are subject to interpretation. A more reliable source of data is necessary, and this takes on three aspects.

(1) There is a real and present need to obtain consensus identification and definition of terms concerning human factors in mishap investigation. Once identified and defined, these terms should be used by future safety investigation boards to specify which variables and to what degree they are a factor in mishap causation.

(2) A central data base should be established to encompass all facets of human factors research in a consistent, comprehensive, cross-reference system. This data base, constantly updated by standardized mishap reports, would serve as the source of reliable data on which future decisions could be made concerning the direction and effectiveness of human factors in mishap prevention.

(3) A method should be devised to regularly take the "human factors temperature" of operational units. This would provide presently nonexistent data on morale, motivation, goals, fears, and needs of crewmembers at unit level. These clearly impact on mishap potential and must be considered in a mishap prevention program.

b. The second directional thrust, and the real heart of increasing the pilot's capacity to deal with the environment, has to do with a reeducation process. The ability to correctly maintain situational orientation, to focus attention on the appropriate environmental cues, and to make accurate judgments when only partial but sufficient information is available, are all skills that are assumed to come with experience. However, as this study has demonstated, experience is only significant in terms of UE time. Highly skilled and time-tested pilots fell into the same fatal traps as the less experienced. We cannot assume that these skills come with time; they must be taught just as motor skills are taught, and at the same time, i.e., at undergraduate pilot training. Furthermore, they should be part of the continuation training programs that keep other skills sharp. Recent efforts by two Russian psychologists, Zavalova and Ponomarenko (4), indicate the inadequacy of traditional training methods to prepare the pilot to deal with nonstandard situations. This approach offers great promise for increasing the pilot's ability to effectively cope with ever-increasing environmental stresses. Other skills that can be taught and maintained are those that enable us to detect, identify, and deal with the source of emotional states which subtly erode performance. These states typically show up as mental distraction in mishaps, and the ability to recognize and deal with the internal cues that invariably accompany them will greatly reduce the decrement in performance they cause.

These recommendations are founded on the conclusions drawn from this study of past mishaps. It is postulated that a coordinated application of human factors principles derived therefrom, both over the short and long run, will significantly reduce the currently stagnated mishap rate. The challenge is great, the possibility for success is high, and the potential benefits to be derived are staggering.

REFERENCES

1. Zeller, A. F. Three decades of USAF efforts to reduce human error accidents, 1947-1977. Advisory Group for Aerospace Research and Development, NATO: 35th Specialists Aerospace Medical Panel Meeting, Paris, 6-10 Nov 1978.

2. Ricketson, D. S., et al. Incidence, cost, and factor analysis of pilot-error accidents in U.S. Army aviation. U.S. Army Agency for Aviation Safety, Fort Rucker, Ala., 1973.

3. Crewse, R. C. Air Force Inspection and Safety Center, Reports and Analysis Division, Norton AFB, Calif. Unpublished study, 1978.

4. Zavalova, N. D., and V. A. Ponomarenko. Psychology of development of special performance skills under nonstandard flying conditions, pp. 264-272. In Soviet military training. AFRP 200-1. Directorate of Soviet Affairs, Air Force Intelligence Service (AFIS/INCF), Bolling AFB, Washington, D.C., Sep 1978.