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DEFINITION OF INVESTIGATIVE AREAS FOR HUMAN-FACTOR ASPECTS OF AIRCRAFT ACCIDENTS

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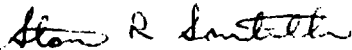
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This technical report has been reviewed and is approved for publication.



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DEFINITION OF INVESTIGATIVE AREAS FOR HUMAN-FACTOR ASPECTS OF AIRCRAFT ACCIDENTS

I. EXECUTIVE OVERVIEW

Introduction

Background--Aircraft mishaps, whether in the military or civilian sectors, represent large losses of lives and property. For operational commanders such losses also represent reduced combat effectiveness. Over the last 30 years, the number and rate of U.S. Air Force aircraft mishaps have substantially declined. According to Santilli (44), the number of Class A (major) mishaps per 100,000 flying hours has decreased from 36.2 in 1950 to 2.8 in 1977. Although the Directorate of Aerospace Safety (16) reported that 1977-78 mishap rates had increased over those of 1974-76, efforts to control aircraft mishaps generally have been successful.

One factor contributing to the reduction of aircraft mishaps has been technological advancement. Increased reliability of avionics, advances in airframe construction, and augmented flight control systems have helped the pilot to maintain positive control in a variety of flight profiles. These same developments, however, have added to the complexity of the piloting task and therefore increased the pilot's cognitive and decision-making requirements.

Another development that has increased the pilot's cognitive and decision-making requirements has been the lowering of the flight ceiling to 100 feet (30.5 m). At 100 feet, pilots must make virtually instantaneous and absolutely accurate decisions to complete mission requirements while maintaining positive flight control.

The complexity of the piloting task is reflected in aircraft mishap statistics. Since the 1950's, pilot factors have been involved in approximately one-half to one-third of all aircraft mishaps. Recent mishap statistics in the Air Force show that pilot factors are involved in over 50% of all aircraft mishaps (44). A recent article by Ricketson et al. (39) estimates that "pilot error" is a factor in 80% of Army aircraft mishaps.

Compared with other factors (e.g., mechanical failure), the level of human involvement in mishaps and their prevention is less understood. Investigative areas are often unspecified; the object of analysis (human behavior) is frequently unpredictable; and determinants of human behavior are interactive. Behavioral breakdown, like mechanical failure, is a dynamic process; variables influencing the former, however, are much more difficult to infer from their effects or outcomes. Moreover, depending on the severity of the accident, pilot-factor data may be unavailable. These problems combine to render investigation of human involvement and assessment of human culpability extremely difficult.

Purpose of This Study--The purpose of this study is to conduct a systematic investigation of pilot factors involved in aircraft mishaps, focusing on Air Force fighter and attack aircraft. Pilot-factor mishaps occur when the pilot fails to maintain positive flight control in a situation where a certain pilot response could have avoided the mishap. In some instances, a pilot-factor mishap will occur because of an error or omission on the part of the pilot. In other instances, however, a pilot-factor mishap will occur not because of a pilot mistake or omission, but because the situational demands of the flight exceed the pilot's capabilities to respond to these requirements.

The systematic nature of this study is reflected in the scope of the research. The study identifies major pilot factors involved in aircraft mishaps, identifies aviation technologies with a high-potential value for diagnosing and/or reducing these pilot factors, and develops research programs aimed at examining these technologies in the context of reducing pilot-related mishaps. The goal of these research programs is to reduce the number and severity of aircraft mishaps associated with the major pilot factors identified herein.

Approach

This section presents the methods used in this research. Figure 1 shows the flow of tasks: The top blocks contain the four major tasks of the research; the lower blocks show the specific data and methods used to complete the tasks.

Following is a task-by-task breakdown of how the research was carried out.

Task 1: Identify Major Pilot Factors Involved in Aircraft Mishaps--As Figure 1 indicates, this task included three subtasks: Review mishap literature; review investigative techniques used by selected aviation safety agencies; and identify major pilot factors, based on a sample of aircraft mishaps.

1. Review Mishap Literature. Mishap literature was examined in order to identify and define the major pilot factors involved in aircraft mishaps. Several sources were used in the literature search, and each article was examined in conjunction with a standardized review form which provided an easily accessible, organized, and thorough abstract.

A major finding of the subtask is the disarray in previous research, reflected in the lack of precision or consistency in conceptual definitions of pilot factors. To help guide the remainder of this research, BDM developed definitions of 10 major pilot factors. These definitions are given in Section II.

2. Review Investigative Techniques Used by Selected Aviation Safety Agencies. The major sources of data used in this report to identify the primary pilot factors involved in aircraft mishaps were official mishap investigation reports. A review was conducted of mishap investigation techniques used by six agencies, representing U.S. civil and military investigative programs and the programs of two non-U.S. organizations.

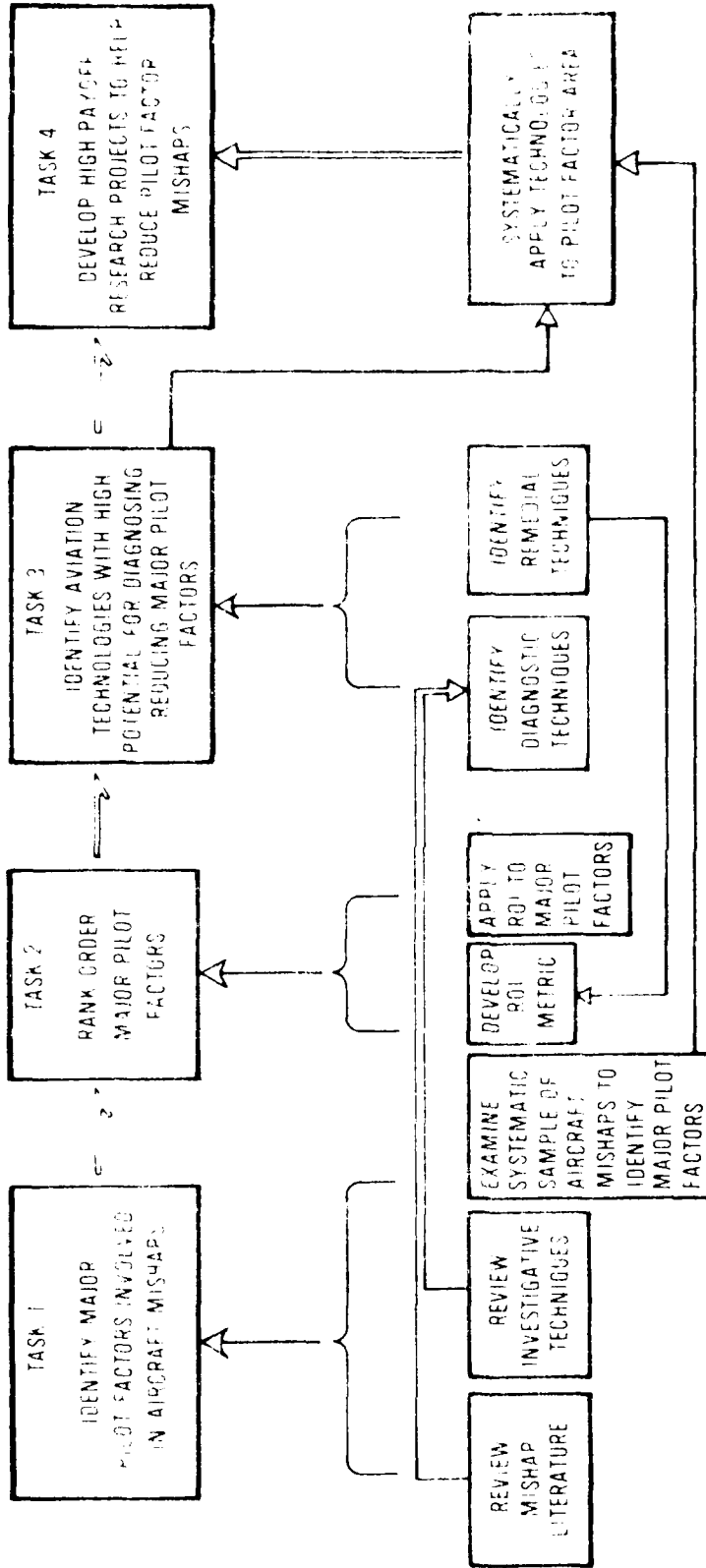


Figure 1. Task flow.

For most of the agencies examined, consistency was lacking across individual mishap investigations. The four major reasons for this are: First, no standard definitions exist for pilot-factor terms used to describe the cause of a mishap. Second, persons charged with conducting the human-factor portion of the mishap investigation vary markedly in their human-factor training and expertise. Third, investigative procedures are not standardized to ensure that consistent, reliable information is extracted from each investigation. Fourth, the pilot is not always available for questioning after the mishap; this suggests that the Air Force may want to initiate a near-mishap investigation procedure with which pilots can be queried in-depth about what happened.

3. Identify Major Pilot Factors Based on a Sample of Aircraft Mishaps. The purpose of this subtask was to conduct a systematic investigation of recent Air Force aircraft-mishap investigations to identify the major pilot factors involved in these mishaps. For the period 1977-78, 70 mishap investigations were examined. These were randomly selected from all U.S. Air Force Class A and Class B mishaps that involved a suspected pilot-factor cause and that involved a fighter, attack, or trainer aircraft.

Guided by a coding form contained in Appendix B of this report and the conceptual definitions of the major pilot factors discussed in Section II, the BDM researchers read the investigative reports and recorded appropriate information. The information included pilot-factor variables that could have been instrumental in the mishap as well as nonpilot factors such as weather conditions, flight profile, and mechanical operation of the aircraft.

Data obtained from this effort were analyzed to determine the pilot factors that occurred most frequently in the 70 mishaps. Six factors occurred in more than 10% of the mishaps: Channelized attention, distraction, disorientation/vertigo, excessive motivation to succeed, overconfidence, and stress.

Task 2: Rank Order the Major Pilot Factors in Relation to a Return-on-Investment Metric-- The purpose of this task was to rank order the pilot factors identified in Task 1, in terms of the potential which research into each factor has to reduce the dollar cost associated with that factor. The three major subtasks were to develop a return-on-investment (ROI) metric; apply the ROI metric to the pilot factors identified in Task 1 and develop a specific ROI; and rank order the pilot factors in relation to the ROI.

1. Develop an ROI Metric. An ROI metric is a tool for estimating the dollar savings in mishap reduction to be realized by undertaking various levels of research into specific factors present in mishaps. This task is concerned specifically with pilot factors. Assuming knowledge of the major pilot factors, three types of information are needed to calculate the ROI:

a. The total dollar cost associated with mishaps resulting from these pilot factors. To estimate how much money can be saved by reducing or eliminating mishaps involving a particular pilot factor, we must know how much money that pilot factor "costs" the Air Force.

b. Knowledge of antecedent conditions that precipitate the major pilot factors involved in mishaps. Knowing the antecedent causes (if any) of

a pilot factor will help in estimating the potential effectiveness of research into eliminating mishaps due to that factor. If the factor itself cannot be directly eliminated, it might be indirectly eliminated by modifying the antecedent factors that cause it to occur.

c. An estimate of how effective research into a specific factor area will be. No matter how much money a specific factor costs the Air Force, if there is no chance of eliminating mishaps due to that specific factor, then no return on investment would be realized by research into that area.

2. Apply the ROI Metric. The dollar cost associated with each major pilot factor was obtained by determining the monetary damage to the aircraft and to the equipment on the aircraft. No dollar estimates were attached to the loss of lives or to the resulting loss of combat effectiveness and training costs because of the arbitrary nature of such estimates.

An estimate of the antecedent causes of major pilot factors was obtained by correlating the occurrence or nonoccurrence of each pilot factor with a host of pilot-related and non-pilot-related factors. The results of this analysis indicated that few antecedent factors were significantly related to the major pilot factors.

The last information needed to calculate the ROI metric was an estimate of how effective research into the major pilot factors would be in helping to reduce or eliminate mishaps due to these factors. The best method for accomplishing this, and the approach employed here, was to scrutinize previous research which had attempted to determine remedies for the major pilot factors. This literature review showed only scattered and fragmented attempts to diagnose pilot factors involved in mishaps and to suggest remedial solutions to these problems. Even when a remedial solution was desired and implemented, its success or failure was not evaluated. The literature concerning the potential effectiveness of research in this area, therefore, is inconclusive; it does not indicate that any pilot factor is either more or less amenable to being studied than any other factor.

3. Rank Order the Pilot Factors in Relation to the ROI. The major pilot factors were rank ordered in terms of expected dollar return as a result of conducting effective research into these factors. Application of the ROI metric gave no indication that research into any of the six major pilot factors would be more or less successful than research into any other factor. Therefore, it is reasonable to assume that each factor investigated, given the same level of research investment, would yield approximately the same percentage of mishap prevention. This means that the return on investment for studying each pilot factor should be directly proportional to the total dollar cost associated with that particular pilot factor; i.e., the greater the dollar cost associated with a particular factor, the greater the ROI to be anticipated by investigating that factor.

Following this logic, the factors would be rank ordered on the ROI metric in the following manner:

- (1) Channelized attention
- (2) Distraction
- (3) Disorientation/vertigo

- (4) Excessive motivation to succeed
- (5) Overconfidence
- (6) Stress

Task 3: Identify Aviation Technologies with a High Potential for Diagnosing and/or Reducing These Pilot Factors--Various aviation technologies were identified by systematically reviewing articles on aircraft-mishap investigations. The articles examined were obtained from a thorough review of the overall literature on aviation safety and were selected from sources similar to those in Task 2.

Each article was reviewed in conjunction with a standardized review form which provided an easily accessible, organized, and thorough abstract for each study. A more extensive discussion of the details of the literature search are contained in Appendix A.

Four general technologies were identified that can be used to study and remedy pilot-factor mishaps:

- Survey "questionnaires"
- Psychological measures
- Simulators
- Training.

Within these general technology areas are a host of specific diagnostic and remedial techniques that could be applied to the major pilot factors.

One key observation from this task is that no one technology is best for any given factor. The successful elimination of any pilot factor requires that multiple technologies be applied in a programmatic fashion.

Task 4: Design Potentially High-Payoff Programs for Investigating Pilot-Factor Aspects of Aircraft Mishaps--The final task of this research was to describe comprehensive programs of research, in the domain of the behavioral sciences, that would aid in investigating aircraft mishaps related to pilot factors. The products of the task included an integrated programmatic approach to the prevention of pilot-factor mishaps, the delineation of several specific research projects aimed at preventing aircraft mishaps, and the proposal of a research project addressed toward eliminating mishaps due to the two major pilot factors--channelized attention and distraction.

Major Findings and Recommendations

A principal reason for undertaking this study was to develop strategies for eliminating major pilot factors involved in Air Force aircraft mishaps. Our approach was to identify the major pilot factors and available aviation technologies capable of reducing or even eliminating mishaps due to these factors. Equipped with this information, specific research programs, matching technologies with pilot factors, were developed with the expressed purpose of preventing aircraft mishaps due to these factors.

In reviewing the literature on aviation safety, particularly the literature pertaining to the identification and prevention of pilot-factor mishaps,

it became apparent that this research is in a state of disarray. The research is characterized by piecemeal attempts to solve various aspects of ill-defined phenomena which may or may not be traceable as causal elements in aircraft mishaps.

The major problem with the research reported in the literature is the lack of a systematic attempt to define and prevent aircraft mishaps. No programmatic attempts have been made on a wide scale to identify and eliminate or reduce pilot factors. Even when a remedial solution has been implemented, its success or failure typically was not followed up by evaluation. Many studies did not even provide conceptual definitions of the pilot factors which they examined.

A lack of consistent definitions is true not only of the research literature, but also of the mishap investigation programs of major aviation safety agencies. The Air Force, for example, investigates all major Air Force aircraft mishaps. Although part of the investigation focuses on pilot factors involved in a mishap, and although the Air Force has identified a number of critical pilot factors, these factors have not been defined clearly.

Integrated Approach To Reduce Pilot-Factor Mishaps--The research of literature and accident reports implies that the key to effective reduction of pilot-factor mishaps is an integrated research program that represents the Air Force commitment to mishap reduction. A program such as this requires three elements: a pilot-factor mishap data collection system to aid in the operational definition of mishap causes, an integrated series of research projects applying remedial technologies to identified pilot factors, and an automated data base management system to provide a needed link between the investigative research and the research to develop solutions to pilot-factor mishaps.

1. Pilot-Factor Mishap Data Collection System. The mishap data collection system includes at least two components:

a. A data collection form containing standard definitions of major pilot factors involved in aircraft mishaps.

b. A pilot-factor checklist to assist the investigator in examining the pilot-factor aspects of a mishap.

2. Integrated Series of Research Projects. An integrated series of research projects are the product of this current research effort. These projects are based on a standard problem-solving strategy and aimed at applying human-factor technologies in the areas identified by the mishap data collection system.

3. Computerized Data Base Management System. Establishment of a pilot-factor data base to provide communication between investigative research and technology application will require detailed front-end analysis, review of existing and emerging computer hardware, and an extensive system architecture effort. These three elements, when in full operation, can be viewed as a pilot-factor mishap reduction system; they are discussed fully in Section V.

Major Pilot Factors Involved and Proposed Research Projects To Prevent Aircraft Mishaps--One component of the integrated approach is to continually identify and attempt to prevent pilot factors involved in aircraft mishaps. Based on an examination of recent Air Force mishaps (fighter, attack, and trainer aircraft), BDM identified six major pilot factors involved in mishaps. These were rank ordered on the basis of potential payoff in mishap reduction to be realized by research on a particular factor. The factors included channelized attention, disorientation/vertigo, distraction, excessive motivation to succeed, overconfidence, and stress. Definitions synthesized by BDM for these terms are given in Section V.

Based on a review of available aviation technologies, BDM has developed 2-, 3-, and 5-manyear research programs targeted to reduce mishaps due to the major pilot factors. Essentially, the programs apply diagnostic and remedial technologies to these pilot factors in an attempt to more completely understand the factors and to develop, implement, and evaluate solutions to the problems.

As a result of this research, we recommend that the Air Force undertake a systematic, programmed approach to investigate and prevent aircraft mishaps related to pilot factors. For maximum payoff on the research investment, the Air Force should concentrate its effort on one program designed to combat the two most costly pilot factors associated with mishaps: channelized attention and distraction. Together these factors were associated with \$254 million in mishap cost over the period 1977-78. Moreover, research leads to the conclusion that they are very similar phenomena.

II. IDENTIFICATION OF MAJOR PILOT FACTORS INVOLVED IN AIRCRAFT MISHAPS

The purpose of this section is to lay the foundation for program development by identifying major pilot factors involved in aircraft mishaps. The first step in this identification process is to review recent aircraft-mishap literature in order to learn more about pilot factors that contribute to mishaps. The second step is to compare the methods by which pilot factors are studied by several safety agencies that conduct investigations into pilot-related mishaps. The final step is to examine 70 recent aircraft-mishap investigations and identify the major pilot factors involved in these mishaps. These three steps will help assure that the pilot factors identified are a valid and reliable representation of all potential pilot-related phenomena.

Review of Literature on Pilot Factors Related to Aircraft Mishaps

A thorough search was made of the overall literature on aviation safety. The articles reviewed in this section were selected from the following sources:

- Keyword search of publications housed at the National Technical Information Service (NTIS)
- Keyword search of publications listed in psychological abstracts
- Review of the journal Human Factors for 1970-79
- Review of the Proceedings of the Annual Human Factors Society Meeting for 1978 and 1979
- Review of selected popular magazines such as Aviation Week and Aviation Digest.

Each article was reviewed using a standardized form which provided an easily accessible, organized, and thorough abstract for each study (see Appendix B, Exhibit B-2). A more extensive discussion of the details of the literature search and an annotated reference section are contained in Appendix A.

Major Investigative Areas--The review of the literature identified 12 major investigative areas pertaining to pilot factors in aircraft mishaps:

- Channelized attention
- Discipline
- Disorientation/Vertigo
- Distraction
- Experience
- Fatigue
- Panic
- Personality characteristics
- Pilot age
- Pilot's physical condition
- Stress
- Workload

Operational Definitions of Investigative Areas--A variety of operational definitions have been used to quantify and measure the pilot factors identified above. The measures used fall into five general categories.

1. Physiological measures are usually used to determine level of workload, fatigue, and stress. They involve monitoring or measuring a physiological response over which most individuals have little control. Measures of heart rate, pre- and postflight sleep duration, and the SAM battery of measures derived from analyses of pre- and postflight urine samples are those most commonly cited in the literature.

2. Pilot's self-report measures include rating scales, questionnaires, and interviews. These are subjective measures that have been used to assess pilots' interpretations of flight situations (e.g., how stressful, how fatiguing) and pilots' attitudes and personality characteristics.

3. The flight surgeon's review of a mishap is contained in the mishap investigation report. This is the most commonly used source of data for the study of pilot factors in aircraft mishaps and provides data for the 12 investigative areas identified, except for stress. Generally, the flight surgeon is responsible for determining and reporting the psychophysiological and environmental factors that have contributed to the mishap. The flight surgeon's decision as to whether or not a pilot factor contributed to a mishap usually serves as the measure of that pilot factor. Investigators, however, have occasionally relied on their own interpretations of the flight surgeon's narrative description of the mishap. Because either the flight surgeon's or the investigator's interpretation may be used, the consistency of the conceptual definitions on which these interpretations are based is crucial to the reliability and validity of this method of measurement. Unfortunately, no standard set of conceptual definitions exists. A more detailed description of the aircraft mishap investigation procedures currently used in the Department of Defense, civil sector, and internationally is presented in the following section.

4. Actual performance measures involve recording pilots' voluntary responses to various experimental flight situations. Experimental flight situations may be simulated or actual. These measures are generally used to assess a pilot's capability to perform various tasks under various environmental constraints. For example, a pilot's information-processing capacity can be inferred by observing and recording his reaction times and ability to respond to certain primary and secondary tasks introduced during an experimental flight.

5. Computer simulation techniques, usually used to measure workload, are computer-based models of aircrew/cockpit environments. They provide a description of the effectiveness of aircrew station integration in lieu of collecting actual performance data.

Approaches to the Study of Pilot Factors in Aircraft Mishaps--To study pilot factors involved in aircraft mishaps, the investigative measures have been used in four basic approaches:

1. Descriptive and correlational studies are generally based on statistical analyses of the data supplied in flight surgeons' investigation reports. The investigator usually has no input into the data base being used to study the pilot factors. Therefore, the information provided in these reports is sometimes reinterpreted by investigators and/or supplemented with additional information regarding the demographic characteristics and experience of the pilot.

Descriptive studies report the frequency with which certain pilot factors are involved in mishaps; correlational studies report the relationships between these "causal" factors and other characteristics of the pilot (e.g., age, experience) or flight (e.g., phase of flight, type of aircraft). These descriptive and correlational data are frequently combined in one report. In this way, new empirical findings are added to an understanding of the problem.

2. Reports based on previous research findings synthesize conclusions drawn and link them together into an operational hypothesis to help explain a particular problem. The investigator neither generates new data nor adds any new empirical evidence to the study of pilot-factor causes of aircraft mishaps. The investigator speculates as to the nature of a pilot-factor problem and its antecedents, and offers suggestions for solutions.

3. Lab and field experiments (computer or flight simulator and actual flight) have been used by investigators to collect their own data by manipulating the pilot's environment, then measuring the effect of the manipulation on the occurrence of pilot factors thought to be causes of aircraft mishaps. The investigator measures the effectiveness of the manipulation either by physiological measures, self-report measures, or observation of the pilot's behavior (actual performance measures). With this approach the investigator can study the effects of new equipment or situations on the pilot's behavior and learn how to structure the environment so that pilot factors are less likely to occur.

4. Surveys used to study pilot factors in aircraft mishaps involve administering subjective rating scales, questionnaires, or interviews (self-report measures) to a representative sample of pilots. In this way, pilots' attitudes, opinions, and interpretations of the flight situation may be obtained. This approach is also used to assess pilots' personalities when exploring hypotheses regarding the relationship between certain personality characteristics and mishap-related behavior. While often used as a supplementary measurement, this technique has strong research support for being valid as a primary diagnostic approach.

Results and Discussion--we have investigated each pilot factor identified at the beginning of this section, according to one or several of the approaches just outlined. The nature of the results of this research is determined, in part, by the investigator's operational and conceptual definitions of the terms and by the approach. The findings regarding each pilot factor will be reviewed, with consideration given when possible to both the definitions and approaches used. A summary of the findings of each article reviewed is provided in Figure 2.

PILOT FACTORS RELEVANT LITERATURE	CHANNELIZED ATTENTION	DISORIENTATION VERTIGO	DISCIPLINE	DISTRACTION	FATIGUE	EXPERIENCE
LIFE CHANGES & ACCIDENT BEHAVIOR						
PERSONALITY CHARACTERISTICS OF THE HIGH ACCIDENT RISK NAVAL AVIATOR						
THE EFFECTS OF FATIGUE ON HEALTH & FLIGHT SAFETY					DEFINES AND ENUMERATES CAUSES	
A STATISTICAL ANALYSIS OF SELECTED HUMAN FACTORS INVOLVED IN AVIATION SAFETY						
THE HUMAN FACTOR IN CYCLIC AIRCRAFT ACCIDENT PATTERNS				HIGH OCCURRENCE OF MISHAPS IN APR. MA. OCT. JAN MAY BE DISTRACTED DUE TO LIFE EVENTS		
REASONS FOR CERTAIN ERRORS IN PILOTING	NO HARD DATA BUT MENTIONED AS A FACTOR		BREACH OF DISCIPLINE A FACTOR			DISCUSSES INSUFFICIENT PREPARATION AS A FACTOR
CHANGE PACE ANALYSIS	CATEGORIZED WITH TASK SATURATION DISTRACTION & INATTENTION ALL COMBINED ACCOUNTED FOR 50% OF 50 MISHAPS		40% OF 50 MISHAPS DUE TO DISCIPLINE BREAKDOWN	SEE CHANNELIZED ATTENTION	13% OF 56 MISHAPS DUE TO FATIGUE	28% OF 56 MISHAPS DUE TO TRAINING 24% TO KNOWLEDGE
QUININE WATER BAD FOR PILOTS ?		INGESTION OF QUININE MAY CAUSE SPATIAL DISORIENTATION				
PILOT FACTOR IN AIRCRAFT ACCIDENTS OF THE GERMAN FEDERAL ARMED FORCES		4% OF 154 MISHAPS DUE TO DISORIENTATION	19% OF 154 MISHAPS DUE TO FAILURE TO OBSERVE REGULATIONS		MANY PROBLEMS OCCUR IN LAST PHASE OF FLIGHT IMPLYING FATIGUE	72% OF 154 MISHAPS CAUSED BY PILOTS WITH LESS THAN 500 HR EXPERIENCE ON THAT AIRCRAFT
FATIGUE IN F811 CREWMEMBERS					LAB EXPERIMENT MEASURING FATIGUE/STRESS	
SPATIAL DISORIENTATION IN GENERAL AVIATION ACCIDENTS		16% OF ALL FATAL MISHAPS IN 1968 1975 DUE TO SPATIAL DISORIENTATION/VERTIGO				18.8% FATAL WEATHER RELATED MISHAPS INVOLVED PILOTS WITH 100 200 HR. 18.2% WITH 1,000-5,000 HR
AN ANALYSIS OF PILOT-ERROR RELATED AIRCRAFT ACCIDENTS			20% OF 74 MISHAPS DUE TO NEGLECT	38% OF 74 MISHAPS DUE TO DISTRACTION	12% OF 74 MISHAPS DUE TO FATIGUE	80% OF 74 MISHAPS DUE TO EXPERIENCE
FATIGUE & AIRCREW MANAGEMENT	DISCUSSED AS MANIFESTATION OF SKILL FATIGUE				FATIGUE PROBLEM DISCUSSED RECOMMENDATIONS MADE	
INCIDENCE COSTS, & FACTOR ANALYSIS OF PILOT ERROR ACCIDENTS IN U.S. ARMY AVIATION	8% OF 452 MISHAPS DUE TO CHANNELIZED ATTENTION	2% OF 452 MISHAPS DUE TO DISORIENTATION/VERTIGO	10% OF 452 MISHAPS DUE TO VIOLATION OF FLIGHT DISCIPLINE	7% OF 452 MISHAPS DUE TO DISTRACTION 19% TO INATTENTION 7% TO PREOCCUPATION	2% OF 452 MISHAPS DUE TO FATIGUE	77% OF 452 MISHAPS DUE TO TRAINING/EXPERIENCE
THE APPLICATION OF AIRCREW OPINIONS ON COCKPIT TASKS & EQUIPMENT TO FLIGHT SAFETY RESEARCH					SUBJECTIVE DATA ON FLIGHT FATIGUE	
A CROSS VALIDATION STUDY OF THE PERSONALITY ASPECTS OF INVOLVEMENT IN PILOT ERROR ACCIDENTS						
PERSONALITY ASPECTS OF PILOT ERROR ACCIDENT INVOLVEMENT						
DETERMINATION OF CRITICAL INTERFACES BETWEEN ENVIRONMENT & ORGANISM CLASS A MISHAPS BY RETROSPECTIVE ANALYSIS	42% OF 78 MISHAPS DUE TO CHANNELIZED ATTENTION	47% OF 78 MISHAPS DUE TO DISORIENTATION	28% OF 78 MISHAPS DUE TO DISCIPLINE BREAKDOWN	37% OF 78 MISHAPS DUE TO DISTRACTION	22% OF 78 MISHAPS DUE TO FATIGUE	
PSYCHOPHYSIOLOGICAL EFFECTS OF AGING DEVELOPING A FUNCTIONAL AGE INDEX FOR PILOTS II TAXONOMY OF PSYCHOLOGICAL FACTORS						
APPLICATION OF A PERFORMANCE MODEL TO ASSESS AVIATOR CRITICAL INCIDENTS						THOSE WITH HIGHEST FLIGHT GRADES & LOWEST ERRORS IN TRAINING HAD A LARGER PORTION OF PILOT FACTOR MISHAPS
HUMAN FACTOR APPROACH TO AIRCRAFT ACCIDENT ANALYSIS					11% OF 345 P3 AIRCRAFT & 24% OF 437 F4 AIRCRAFT MISHAPS DUE TO FATIGUE	
ENDOCRINE METABOLIC EFFECTS IN SHORT DURATION HIGH WORKLOAD MISSIONS FEASIBILITY STUDY					PHYSIOLOGICAL MEASURES OF INFLIGHT STRESS, INDICATING FATIGUE	
BEHAVIORAL ASPECTS OF AIRCREW MENTAL WORKLOAD						

Figure 2. Matrix of causes--Literature review.

RELEVANT LITERATURE	PILOT FACTORS	PANIC	PERSONALITY CHARACTERISTICS	PILOT AGE	PILOT'S PHYSICAL CONDITION	STRESS	WORKLOAD
LIFE CHANGES & ACCIDENT BEHAVIOR						LIFE CHANGES & CRISIS AS SOURCE OF STRESS	
PERSONALITY CHARACTERISTICS OF THE HIGH ACCIDENT RISK NAVAL AVIATOR			LITERATURE REVIEW INDICATING CORRELATION BY A CAUSAL PERSONALITY				
THE EFFECTS OF FATIGUE ON HEALTH & FLIGHT SAFETY						STRESS LISTED AS A PSYCHOLOGICAL CAUSE OF PILOT FATIGUE	
A STATISTICAL ANALYSIS OF SELECTED HUMAN FACTORS INVOLVED IN AVIATION ACCIDENTS			NO RELATIONSHIP BETWEEN RHYTHMIC CAUTION HAYS IN MISHAP				
THE HUMAN FACTOR IN AIRWAY ACCIDENTS							
MISAPPROPRIATE ERRORS IN PILOTING			THE EFFECTS OF SELF-CONFIDENCE & SELF-RELIANCE AS FACTORS				
CHANGE PACE ANALYSIS			EVEN IN THE MISHAPS DUE TO PILOT OVERCOMMITMENT			25% OF THE MISHAPS DUE TO MISSION STRESS 15% DUE TO PERSONAL STRESS	SEE CHANNELIZED ATTENTION MISSION COMPLEXITY IS MAJOR PROBLEM
QUININE WATER PAD FOR PILOTS							
PILOT FACTOR IN AIRCRAFT ACCIDENTS OF THE GERMAN FEDERAL AIR FORCE				LOW INCIDENCE OF MISHAPS BETWEEN 35 & 43 INCREASE AT 44 1957 AT 28 76			
FATIGUE IN THE CREWMEMBERS					LAB EXPERIMENT MEASURING FATIGUE STRESS		
SPATIAL DISORIENTATION IN GENERAL AVIATION ACCIDENTS				HIGHEST INCIDENCE OF WEATHER RELATED MISHAPS BETWEEN 40 AND 45			
AN ANALYSIS OF PILOT ERROR RELATED AIRCRAFT ACCIDENTS							
FATIGUE & AIRCREW MANAGEMENT						DISCUSSES TESTS OF STRESS AS INDICATORS OF FATIGUE	
INCIDENCE COSTS & FACTOR ANALYSIS OF PILOT ERROR ACCIDENTS IN U.S. ARMY AVIATION	1% OF 452 MISHAPS DUE TO PANIC		3% OF 452 MISHAPS DUE TO EXCESSIVE MOTIVATION 10 SOLICITED 13% TO OVERCONFIDENCE 2% TO UNDERCONFIDENCE		VERY LOW % OF 452 MISHAPS DUE TO DRUG OR ALCOHOL INTAKE		2% OF 452 MISHAPS DUE TO TASK OVERSATURATION
THE APPLICATION OF A CREW OPINIONS ON COCKPIT TASKS & EQUIPMENT TO FLIGHT SAFETY RESEARCH							WORKLOAD AT EACH PHASE OF FLIGHT SUBJECTIVELY ASSESSED BY AIRCREW
A CROSS VALIDATION STUDY OF THE PERSONALITY ASPECTS OF INVOLVEMENT IN PILOT ERROR ACCIDENTS			NO PERSONALITY DIFFERENCES BETWEEN PILOT ERROR ACCIDENT GROUPS				
PERSONALITY ASPECTS OF PILOT ERROR ACCIDENT INVOLVEMENT			PILOTS IN MISHAPS FOUND TO BE GROUP DEPENDENT PRACTICAL & SHREWD				
DETERMINATION OF CRITICAL INTERFACES BETWEEN ENVIRONMENT & ORGANISM CLASS A MISHAPS BY RETROSPECTIVE ANALYSIS	28% OF 78 MISHAPS DUE TO GENERAL ADAPTATION SYNDROME		24% OF 78 MISHAPS DUE TO OVERCONFIDENCE 4% DUE TO UNDERCONFIDENCE	AVERAGE AGE OF PILOTS INVOLVED IN THE 78 MISHAPS REVIEWED IS 32 YR	14% OF 78 MISHAPS DUE TO PRE EXISTING ILLNESS OR DEFECTS 4% DUE TO NUTRITIONAL STATE 3% DUE TO DRUGS		33% OF 78 MISHAPS DUE TO TASK DEMANDS 4% DUE TO MULTIPLE TASK
PSYCHOPHYSIOLOGICAL EFFECTS OF AGING DEVELOPING A FUNCTIONAL AGE INDEX FOR PILOTS TAXONOMY OF PSYCHOLOGICAL FACTORS				DISCUSSES RELATIONSHIP OF 14 FACTORS TO AGE AND THE AGING PILOT			
APPLICATION OF A PERFORMANCE MODEL TO ASSESS AVIATOR CRITICAL INCIDENCE			FINDINGS IMPLY THAT OVERCONFIDENCE CONTRIBUTES TO PILOT FACTOR MISHAPS				
HUMAN FACTOR APPROACH TO AIRCRAFT ACCIDENT ANALYSIS							
ENDOCRINE METABOLIC EFFECTS IN SHORT DURATION HIGH WORKLOAD MISHAP FEASIBILITY STUDY						PHYSIOLOGICAL MEASURES OF FLIGHT STRESS FACTOR MANIPULATED AND MEASURED	WORKLOAD MANIPULATIONS AFFECTS LEVELS OF STRESS AND FATIGUE
BEHAVIORAL ASPECTS OF AIRCREW MENTAL WORKLOAD							MEASUREMENT BY SUBJECTIVE OPINIONS MEASUREMENT OF SPARE MENTAL CAPACITY & PRIMARY TASK MEASURES

Figure 7 (continued).

1. Channelized Attention: Three studies based on statistical analyses of the data provided in flight surgeons' investigation reports have identified channelized attention as a factor contributing to aircraft mishaps. One study (Directorate of Aerospace Safety, 16) examined 59 U.S. Air Force mishap investigation reports (1977-78) that cited pilot factors as contributing causes. Channelized attention was defined in this report as the phenomenon that occurs "when a pilot concentrates on a task being performed to the point that other cues of impending disaster are not noticed." It was combined in the analyses with distraction, inattention, and task saturation, all of which were categorized as "pilot-induced control loss." This combination of factors was found to have contributed to 50% of the mishaps reviewed. From an analysis of 452 U.S. Army aircraft mishaps that occurred in 1971-72, Ricketson et al. (39) found that only 8% were attributed to channelized attention; however, no definition of the term was provided. Santilli (44) has defined channelized attention as "the focusing of attention on a specific task at the expense of not attending to others of a higher or more immediate priority." In his review of 76 U.S. Air Force mishap investigation reports in 1977-78, he found channelized attention to have been involved in 42% of the mishaps. The inconsistency of these findings is attributed to differences in definitions of channelized attention, to differences in types of aircraft and missions involved in the three studies, and to the unreliability of flight surgeons' reports.

In a study incorporating results from available tests and research on fatigue and synthesizing information from dozens of articles written by doctors, crewmen, and safety agencies, Mroska (34) referred to a phenomenon called "fixed vision." This phenomenon is presumably similar to channelized attention; however, he offered no definition. He concluded from his review of previous research findings that fixed vision is a manifestation of fatigue in the pilot. In a similar type of study, Dimitrov (15) discussed a phenomenon resembling channelized attention which he attributed to insufficient preparation.

2. Discipline. Each Pilot's Information File contains the Air Force regulations and the standard operating procedures pertaining to each type of mission. Any violation of these rules is considered a violation of flight discipline. While failure to observe flight regulations and procedures is relatively easy to define and detect, determining whether or not the violation was intentional is difficult.

Dimitrov (15) discussed breach of discipline as an important factor in aircraft mishaps. Though he offered no hard data, several case histories were presented involving breach of discipline and its possible pilot-personality correlates, such as overconfidence.

Five studies reviewed have addressed the frequency with which discipline breakdown has been involved in aircraft mishaps. Ricketson et al. (39) found that 10% of the 452 U.S. Army pilot-factor aircraft mishaps they reviewed had been attributed to violation of flight discipline. Flackenberg (18) reported that failure to observe regulations was involved in 19% of the 154 German Federal Armed Forces pilot-factor mishaps reviewed. In Kowalsky et al.'s (29) model for categorizing NTSB mishap data, neglect was identified as a critical-condition category. The flight events that made up the category

consisted of such discipline violations as improper use of checklists, clearance deviation, and improper rest/procedure. This critical-condition category was responsible, at least in part, for 20% of the mishaps considered. Santilli's (44) analysis showed discipline breakdown to have been involved in 28% of the 76 U.S. Air Force pilot-factor mishaps included in his study. The Directorate of Aerospace Safety (16) attributed 47% of the mishaps they studied to discipline breakdown.

3. Disorientation/Vertigo. The literature shows general agreement as to the definitions of disorientation and vertigo. Disorientation refers to an incorrect appraisal of an individual's position, location, or movement. In aviation, the incorrect appraisal specifically relates to the attitude (orientation) or motion of the pilot and his plane with respect to earth. On some occasions, disorientation in the air consists of true vertigo (sensations of rotar motion of the external world or of the individual) and/or dizziness, (sensations of unsteadiness with a feeling of movement within the head) (e.g., Kirkham et al., 28). When referred to by pilots, vertigo almost invariably means their awareness of any of the various forms of disorientation. "Pilot vertigo" and the more technical term "spatial disorientation" are virtually synonymous in the language of pilots and are, therefore, presented together in this section.

In a study focusing specifically on spatial disorientation as a pilot factor involved in civilian aircraft mishaps, Kirkham et al. reported that spatial disorientation was involved in 16% of all fatal mishaps that occurred between 1965 and 1976. Moreover, when spatial disorientation was associated with a mishap, it was a fatal mishap 90% of the time. The study also found that the greatest incidence of spatial disorientation occurred in pilots between the ages of 41 and 49 and in pilots who had less than 500 hours of flying experience. These data were supplied by the National Transportation Safety Board's mishap investigation reports.

Other studies reporting the frequency with which certain pilot factors occur in mishaps have found disorientation/vertigo to have been involved in 24% of the 441 U.S. Army pilot-factor aircraft mishaps (Ricketson et al., 39) and 12% of 104 senior Federal Armed Forces pilot-factor aircraft mishaps (Blackenberg, 17). Santilli (44) found that 47% of 76 U.S. Air Force pilot-factor mishaps were due to situation disorientation. He stressed the cognitive aspects of situation disorientation as opposed to physical aspects which are more characteristic of vertigo. Again, the discrepancies in these findings may be attributed to differences in the types of aircraft and missions involved in the studies, to the unreliability of flight surgeons' reports, and to the absence of standard definitions.

Little research into the antecedent causes of spatial disorientation has been done; however, an interaction between vestibular and visual sensory input that results in spatial illusions is generally agreed upon as a cause. The Armed Forces Institute of Pathology suggests that quinine contained in tonic water, for example, may disrupt inner ear functions and thus produce disorientation or delayed awareness reactions (Caughletti, 17).

4. Distraction. Confirmed in the literature on distraction as a pilot factor in aircraft mishaps, controls found the inability to operationally

and conceptually distinguish it from channelized attention, inattention, and preoccupation--all of which the flight surgeon must consider separately when completing his portion of the investigation report. Distraction has been conceptualized as the first step toward channelized attention; that is, the pilot's attention is distracted from the primary flying task and channelized toward an abnormal condition (39). Santilli (44) presented distraction, channelized attention, and inattention as separate subcategories of concentration; he defined distraction as "the interruption of focus of attention on a specific task by the introduction of a non-task-related stimulus." The Directorate of Aerospace Safety (16) described distraction as that phenomenon which occurs "when a pilot's attention is drawn away from the task at hand," but combined it with channelized attention and task saturation in the analyses. In a somewhat different vein, Kowalsky et al. (29), in their model for categorizing NTSB mishap data, identified distraction as one of ten "critical condition categories." This category consisted of flight events thought to be possible distractions for the pilot, such as excessive communications with Air Traffic Control, last minute changes or other confusion, hurrying, poor destination weather, and ashtray fire. Distraction, then, was considered to be a pilot factor in the mishap when any of these flight events were reported.

Ricketson et al. (39) reported that 7% of the mishaps they reviewed were due to distraction; 19% to inattention; and 7% to preoccupation. He did not discuss the conceptual differences between these three factors. Santilli (44) found 37% of the mishaps he reviewed to have been attributed by flight surgeons to distraction. Similarly, 38% of the civilian aircraft mishaps studied by Kowalsky et al. (29) were attributed to distraction. The Directorate of Aerospace Safety (16) cited the combination of distraction, channelized attention, inattention, and task saturation as a cause in 50% of the mishaps reviewed. While these findings are slightly more consistent than the findings on other pilot factors, the methods of conceptualizing and measuring distraction are still not standard.

Dean (12) studied aircraft mishap patterns and linked them, in part, to pilots' life events and environmental events that occur cyclically. His data were not directly related to distraction per se; rather, he inferred that distraction is one reason that aircraft mishaps occur more often during some months than others. Specifically, his analysis of CF-104 aircraft mishaps showed April, July, October, and January to be high-rate months. He offered explanations such as: in April, personnel whose tours of duty end in July are preparing to return to Canada and are preoccupied with packing; distracting bird activity is high in April; in October, preoccupation with planning Christmas celebrations and vacations is a factor; in January, personnel are attempting to pay Christmas debts and still meet daily financial obligations. The speculative nature of these relationships is emphasized.

5. Experience. The literature addresses several aspects of pilot experience. First is the total flying time a pilot has acquired in all types of aircraft. Second is "UE time," which refers to the total flying time a pilot has acquired in the type of aircraft in which the mishap occurred. These two aspects of pilot experience are measured in number of hours. A third aspect is whether or not a pilot has ever performed the mishap task before, and if so, how recently. All of these measures are aimed at assessing the pilot's proficiency, which is assumed to be a direct correlate of experience. These data are recorded in the investigation report.

Three out of 11 pilots involved in the accident cases they reviewed were attributed to the lack of crew resource management. Analysis by the Directorate of Air Accidents and Investigations of the factors included in the study were classified as follows: weather, crew resource management, here, was considered a factor when the flight crew's total flying time were low and obviously influenced by weather. Crew resource management, the situation with which he was faced, was considered a factor when the pilot was performing a measure (event proficiency) with a high level of proficiency (more than 111) familiar with the system even though the level of proficiency was 37% of the cases. Database control of the accident cases reviewed to have been at least partially influenced by the lack of familiarity with and competency to operate the system.

Other studies on pilot performance have reported results in terms of number of cases reviewed. Kirchner's data showed that 45% of the pilots involved in flight accidents had less than 10 hours of JF flying time, 31% had less than 100 hours, and 15% had less than 500 hours. Kirchner et al. (24) in their study of pilot participation in civilian mishaps, found that 20% of the pilots involved in fatal weather-related spatial disorientation accidents had less than 100 hours of total flying time and 19.2% had 1,000-20,000 hours. These two percentages were interpreted by the investigators as reflecting a bias against flight (44) reported that the mishaps he studied occurred with frequently young pilots who had less than 150 or more than 10,000 hours of flight time. Overconfidence of experienced pilots is a factor which may explain the findings of Kirchner et al. and the other investigators may have been a confounding factor.

4. Fatigue and stress - These two concepts are viewed together here because they have been shown to be highly interrelated and difficult to separate. In one instance, the same measures were used to assess both concepts. As a result, much of the information derived from these two factors conceptually rather than statistically is overlapping.

Benit et al. (10) and Smith (26) both discussed the difficulty in precisely defining fatigue. Both investigators attempted to explain fatigue by breaking it down into various types of fatigue: physical, mental, and psychological fatigue. Mental fatigue is defined in terms of energy and skill fatigue. Both investigators discussed possible causes of fatigue, including stress and mental workload. In general, mental workload is defined as a causal factor of crew fatigue and is related to the limits of crew duty time and the time constraints of the task. As the problem is better understood.

Frequency data indicated that fatigue was a factor in 40% of the cases reviewed. Fatigue is considered a factor in 11% of the cases reviewed, depending on type of accident. (See Table 1, p. 10, ref. 10).

Clark et al. (11) examined a number of accidents involving fatigue and stress as part of the total investigation of the B-111 aircraft. Fifteen accidents involving fatigue and stress were reviewed. Each two-man crew consisted of a commander and a co-pilot. Subjective fatigue, and, and, and flight time, flight time, flight time, flight time, flight time, and stress and workload were also reviewed. The data are presented in Table 1.

demanding mission was assigned to one crew from whom urine samples were obtained and analyzed for epinephrine, norepinephrine, 17-hydroxycorticosteroids, sodium, potassium, and urea. The data showed that the crews experienced moderate fatigue and stress, aggravated by substantial physical discomfort, from which they recovered quite rapidly. An interesting secondary finding was the absence of a relationship between fatigue scores and sleep duration. That is, preflight sleep inadequacy did not lead to unusually high fatigue increments, nor did high fatigue increments lead to unusually high postflight sleep duration. This finding has important implications for the fatigue frequency data presented in the flight surgeons' reports since those analyses were based on number of hours slept prior to mission as an indication of fatigue.

In a similar type of study, Storm et al. (54) tested an augmented assembly of measures for assessing the relative merits of various flight instrumentation systems. The USAF School of Aerospace Medicine (SAM) stress battery was included as a measure of stress/fatigue. This battery involves urine analyses and self-estimates of subjective fatigue. Eight pilots were assigned to three different flight paths associated with different workloads. The data showed postflight feelings of mild fatigue and behavioral support for the urinary findings. The authors concluded that the SAM stress battery was a useful addition to the flight instrumentation research program.

In addition to data that discuss stress as an indicator of fatigue, several studies deal with stress separately from fatigue. Like fatigue, however, stress is difficult to define and isolate. The Directorate of Aerospace Safety (16) has identified and studied two types of stress. The first is mission stress which refers to excessive stress generated by the conditions surrounding a mission, usually a high-visibility mission. Analyses showed mission stress to have been involved in 25% of the mishaps reviewed. Second is personal stress which may be a factor if a pilot has unusual or severe personal problems. Alkov (1) discussed life changes and crises in the pilot as a source of this type of stress. The Directorate of Aerospace Safety found personal stress to have contributed to 20% of the mishaps included in their study.

7. Panic. Though panic is a factor on the checklist of the investigations report, which flight surgeons must consider, it is rarely cited in the literature as an important cause of pilot-factor aircraft mishaps. Ricketson et al. (39) found only 1% of the mishaps they reviewed to have been attributed to panic. Santilli (44) referred to the general-adaptation syndrome (G.A.S.), defined as "the heightened physiological state automatically assumed by the organism when faced with a crisis to prepare him to 'fight or flee.'" This accounted for 28% of the mishaps reviewed in his study, and although not referred to as panic specifically, it appears to be a similar phenomenon. Panic has received little attention in the literature, but it seems intuitively to be an important factor, supported by the findings regarding G.A.S.

8. Personality. Personality characteristics regarded in the literature as the best personality predictors of aircraft mishaps are accident proneness, excessive motivation to succeed, and overconfidence.

One investigation of accident proneness was a statistical analysis of over 2,400 aviation mishap reports aimed at determining whether or not

a relationship exists between aircraft mishap dates and the year in last 10 days. The analysis yielded no significant relationships (Erickson and Delavan, 9).

Excessive motivation to succeed is an item on the flight surgeon's checklist which the flight surgeon must consider when reviewing aircraft mishaps. Ricketson et al. (39) found that it was mentioned as a factor in only 3% of the mishaps under study. The Directorate of Aerospace Safety (16), defining the concept more broadly as "overcommitment" to the flight mission, found it to have been a factor contributing to 10% of the mishaps. The discrepancy between these two findings is one of differences in the ways of conceptualizing excessive motivation to succeed.

Overconfidence, also an item on the flight surgeon's checklist, was named in 13% and 24% of the mishaps in analyses by Erickson et al. (39) and Santilli (44), respectively. Similarly, Sanders (42) found that pilots with the highest flight grades and lowest errors in training were involved in a larger proportion of pilot-factor mishaps. These findings imply that overconfidence can be detrimental to a pilot's success in flying.

In an effort to identify personality characteristics of pilots who have been involved in aircraft mishaps, Sanders et al. (42) administered Cattell's Sixteen Personality Factors Questionnaire (16 PF) to pilots who had and had not been involved in mishaps. Postmishap personality analyses revealed three personality measures that correctly distinguished the pilots as to their prior pilot-factor mishap involvement. Pilots involved in mishaps were more group dependent (*vs* self-sufficient), practical (*vs* imaginative), and shrewd (*vs* forthright). In an attempt to replicate these findings, however, Sanders et al. (43) failed to discriminate mishap-involved from mishap-free pilots with respect to personality characteristics measured by the 16 PF.

9. Pilot Age. All mishap investigations report the age of the pilot involved, so the measure of pilot age is reliable and valid. The relationship of pilot age and aircraft mishaps, however, appears to be inconsistent. Flackenberg (18) found, for helicopter and propeller-aircraft types, a gradual increase in mishaps for pilots from 21 to 27 years, a substantial increase between the ages of 29 and 31, a gradual decrease from 32 to 42 years, and a slight increase for the age groups of 47 and above. Reporting a similar trend, Santilli (44) found that mishaps occurred most frequently among pilots between the ages of 27 and 29, decreased with age from 30 to 41, and increased somewhat among pilots over 42. Kirkham et al. (28) reported that the highest incidence of fatal weather-related mishaps occurred in pilots between the ages of 40 and 49. Again, it is difficult to compare these findings with others that report data for a specific type of mishap only.

10. Pilot's Physical Condition. A pilot's physical condition, including drug and alcohol intake and preexisting illness or defect, is assessed after a mishap by flight surgeons' exams or autopsies. Ricketson et al. (39) found that a very low percentage of mishaps were due to drug or alcohol intake. Santilli (44) reported that 14% of the mishaps he reviewed were due, in part, to pilots who had preexisting illnesses or defects, 4% to pilots in poor nutritional states, and 3% to pilots who had taken drugs. While the

literature has not shown the pilot's physical condition to be a major contributor to aircraft mishaps, the flight surgeon's investigation is so detailed with regard to the preexisting physical condition of the pilot that we considered it a major factor worthy of further study.

11. Workload. Aircrew mental workload has been measured in a variety of ways. Williges and Wierwille (57) classified the behavioral-research literature pertaining to the measurement of aircrew workload into the general categories of subjective opinion, spare mental capacity, and primary-task metrics. They concluded that no single measure can be recommended as the definitive behavioral measure of mental workload and that the most promising assessment procedure should include multiple measures from all three of the general categories, as well as physiological correlates. The literature reflects this attitude with the variety of ways in which workload has been studied.

Through a survey of aircrew opinions, Rolfe and Chappelow (41) assessed aircrew workload at each phase of flight. The highest ratings of all aircrew were given to the preflight planning and mission phases. Pilots also rated approach and landing as high-workload phases of flight. A task analysis of sorties that require physical workload, perceptual workload, and mental workload was presented. These authors considered two aspects of the flying task to underlie other pilot factors involved in aircraft mishaps. These two are 1) physical and mental workload, and 2) compatibility between the equipment provided and human capabilities.

In support of Rolfe and Chappelow's (41) assumption regarding workload, the Directorate of Aerospace Safety (16) concluded that mission complexity is a major underlying problem contributing to aircraft mishaps. This was based on their finding that half of their mishaps involved distraction, inattention, task saturation, or channelized attention, all of which are tied to mission complexity. Similarly, Storm et al.'s (54) manipulation of mission workload, which effectively induced varying amounts of stress and fatigue, implied that workload is a contributor to other pilot factors identified as causes of aircraft mishaps. Santilli's (44) frequency data gave further empirical support to the importance of workload as a contributing factor in mishaps. His study showed that overcommitment, defined as "the assignment of task demands and multiple tasks that exceed the pilot's capability," was involved in 36% of the mishaps he reviewed. Inconsistent with these findings, however, are data presented by Ricketson et al. (39) which indicate that only 3% of their mishaps were due to task oversaturation.

Proposed Conceptual Definitions of Pilot Factors--One of the most outstanding characteristics of the literature reviewed is the lack of precision and consistency in the conceptual definitions of the pilot-factor investigative areas. Often the pilot factors under study are not defined. When definitions are present to help interpret findings, they are usually those of the investigator, even though the data used in the study were collected using definitions of different flight surgeons. Mishap investigators, especially flight surgeons who supply a majority of the data used in mishap research, need a standard set of definitions to which they may refer when reporting on the pilot-factor causes of mishaps. This would greatly increase the reliability and validity of related research findings.

We have synthesized descriptions and fragments of definitions from the literature into concise definitions for the ten most ambiguous major pilot factors. Then, to conduct a more systematic investigation of recent aircraft mishaps investigation reports, we have used these definitions to interpret flight surgeons' narrative descriptions of events surrounding the mishaps.

- Channelized Attention - A behavioral phenomenon that occurs when a pilot's full attention is focused on one stimulus to the exclusion of all others. This becomes a problem when the pilot fails to perform tasks or process information of a higher or more immediate priority and thus fails to notice or has no time to respond to cues of impending disaster.

- Disorientation - A loss of one's place-in-space that occurs when a pilot's perception of the aircraft's attitude or motion is incongruent with respect to Earth. This is due to inadequate sensory stimuli, an incorrect interpretation of sensory stimuli due to limitations in sensory receptors, incorrect selection of competing stimuli, or the absence of a general cognitive framework that realistically orients the operator within his environment.

- Vertigo - A form of physiological disorientation that occurs when a pilot senses that he or the external world is rotating. Any form of disorientation becomes a problem when a pilot is not cognizant of being disoriented and responds according to his incorrect appraisal of the situation, or when the pilot is cognizant of being disoriented but is unable or does not have enough time to correctly reorient himself while tending to other vital flying tasks.

- Distraction - A behavioral phenomenon that occurs when a pilot's focus of attention on flying tasks is interrupted by a stimulus unrelated to those tasks. This becomes a problem when the pilot fails to refocus attention on flying tasks of a higher or more immediate priority in time to recognize and respond to cues of impending disaster.

- Excessive Motivation To Succeed - A personality characteristic that predisposes a pilot to set unrealistically high standards for himself and try to perform tasks for which he is knowingly ill-prepared. This becomes a problem when mission success is afforded a higher priority than caution, judgment, or known restrictions.

- Fatigue - A degraded capability to perform some specified tasks that occurs when a pilot's present cognitive or physical capacity has been exceeded over some period of time. This becomes a problem when thought processes and/or muscular reflexes are retarded to the point that the pilot cannot meet the workload demands of a flight.

- Overconfidence - A personality characteristic that a pilot may develop with experience or with positive reinforcement during training. It predisposes the pilot to overestimate personal ability, the ability of others, and/or the ability of the aircraft. It becomes a problem when the pilot attempts to perform tasks that exceed personal or aircraft capabilities.

- Panic - A heightened psychophysiological response state that a pilot may experience when he is stressed to the point that his adaptive mechanisms completely collapse. In such a situation, the pilot is seized with sudden, uncontrollable paralyzing terror which inhibits him from performing the mental and physical tasks requisite for safe-flight mission completion.

- Stress - A heightened psychophysiological response state experienced when a pilot perceives that the workload demands of the flight may exceed his capabilities and that the successful completion of the flight is thus threatened. In such a situation, the pilot's adaptive mechanisms become severely taxed. Problems arise when his adaptive mechanisms are taxed to the point that they collapse and the pilot is unable to meet the workload demands of the flight.

- Workload - The amount of activity, mental and physical, requisite for safe mission completion. This becomes a problem when, for various reasons, the workload demands of a mission exceed the pilot's capabilities to meet those demands in the amount of time available.

Review of Techniques Used by Selected Aviation Safety Agencies To Investigate Mishaps

Air Force mishap investigation reports were the major source of data used in this report to identify the primary pilot factors involved in aircraft mishaps. Since mishap investigations play such an important role in diagnosing and understanding the causes of aircraft mishaps, the techniques with which mishap information is collected are also important. This section will compare the investigative techniques of six organizations and provide recommendations as to how the Air Force's investigation procedures may be improved. The six organizations selected for study were the U.S. Air Force, Army, and Navy; the National Transportation Safety Board (NTSB); the Canadian Forces; and the Royal Air Force (RAF) of the United Kingdom.

The information presented here was obtained from official agency regulations and discussions with members of the agencies. Table 1 presents the written materials reviewed for this section. Information about the RAF investigative programs was obtained exclusively from discussions with RAF personnel; official documents were unavailable.

Conduct of an Aircraft Mishap Investigation--After a mishap occurs, an investigation board is convened and charged with uncovering the causes of the mishap. Generally the intention of the investigation process is to obtain information that can be used to prevent similar mishaps. Except for NTSB, the board typically consists of a president who is a rated pilot, a maintenance officer who is knowledgeable about the aircraft, a medical officer, and a recorder. The medical officer (typically a flight surgeon) is charged with evaluating the human-factor aspects of the mishap. He also determines the causes of injuries sustained in the mishap and analyzes the egress and life-support equipment available.

TABLE 1. DOCUMENTS REVIEWED FOR INVESTIGATION TECHNIQUES

<u>Agency</u>	<u>Documents</u>
Air Force	AFM 127-1, Aircraft Accident Prevention and Investigation, 1972; AFR 127-2, The U.S. Air Force Mishap Prevention Program, 1979; AFR 127-4, Investigating and Reporting U.S. Air Force Mishaps, 1978
Army	AR 95-5, Aircraft Accident Prevention, Investigation, and Reporting, 1975
Navy	NAVAIR 00-80T-67, Handbook for Aircraft Accident Investigators, 1973
NTSB	Outline Human Factors Investigation/Report
Canadian Forces	CFP 175(2), Aid to Accident/Incident Investigation, 1979; Flight Surgeon's Accident/Incident Check List, 1977, DCIEM Report 75-R-1098, Investigation of Human Factors in Aircraft Incidents and Accidents, 1975

All agencies examined here follow this investigation model to some extent. There are, however, some important differences. The agencies are compared on three critical dimensions of the human-factor portion of the analysis. These dimensions are reflected in the following questions.

- (1) What human factors are investigated?
- (2) Who is charged with conducting the human-factor investigation?
- (3) Who makes the final decision as to the human factors involved in the mishap?

Table 2 presents an overview of each agency based on the answers to these three questions. The table shows that five of the six agencies used medical officers or flight surgeons to conduct the human-factor portion of the mishap investigation. This represents only a small portion of their responsibilities. The flight surgeons are also charged with examining the causes and extent of injuries suffered by persons aboard the aircraft and with analyzing the egress and life-support equipment involved. Only the RAF sends investigators specially trained in human factors to investigate these aspects of a mishap.

For four of the six agencies, the human-factor investigator is actually a member of the unit or installation in which the mishap occurred. The NTSB and the RAF send investigators from their central headquarters to the mishap.

The U.S. Army, Navy, and Air Force focus on the same set of human factors to investigate. Exhibit B-2, Appendix B, presents the list of factors the

TABLE 2. OVERVIEW OF CRITICAL ASPECTS OF AIRCRAFT MISHAP INVESTIGATION PROGRAMS FOR SIX AGENCIES

	<u>Human factors exhibited</u>	<u>Human-factor investigator</u>	<u>Final evaluation of human-factor causes</u>
Air Force	See exhibits B-3, B-4*	Flight surgeon (local)	AF Inspection and Safety Center
Army	See exhibits B-3, B-4	Flight surgeon (local)	Major command (e.g., FORSCOM, TRADOC)
Navy	See exhibits B-3, B-4	Flight surgeon (local)	Naval Safety Center
NTSB	Primarily injury related	Flight surgeon (local)	NTSB Board
Canadian	See exhibit B-5	Flight surgeon (local)	Major command
RAF	Not available	Human-factor investigator (central)	Board itself

*Appendix B exhibits

flight surgeons use to indicate the presence or absence of selected human factors. The form, developed jointly by the services in the late 1960's, provides the flight surgeon with a long list of potential human factors involved in a mishap, but with no definitions of these factors. Thus the definition of each factor is left to the discretion of the investigating flight surgeon.

The Air Force, Army, and Navy also examine personal data for crewmembers of the mishap aircraft. Exhibit B-4 presents a copy of these variables. The Navy has launched an unofficial attempt to obtain data on pilot life stress which is hypothesized to impact on pilot performance in the cockpit. Life stress is characterized by events such as divorce and death in the family.

The NTSB is not concerned primarily with the human-factor causes of a mishap. It, instead, focuses on injuries to the crew and passengers of the aircraft and on the egress systems. Only in circumstances where human-factor causes are obvious (for instance, a pilot who has a high blood alcohol count) will an NTSB investigation report such causes. One reason for this particular emphasis is that the NTSB reports are part of the public record. Since human-factor causes are often difficult to support, the NTSB discourages speculation on them as causes of mishaps. In the other agencies examined here, the primary purpose of the investigation is to understand mishap causes with the aim to prevent these mishaps in the future. Since the results of these investigations are not subject to public scrutiny, investigators are encouraged to make reasoned judgments as to human-factor causes of mishaps.

Exhibit B-5 presents the personal data and human factors that the Canadian Forces' flight surgeons examine. These factors are taken from the Flight Surgeon's Accident/Incident Check List (1977). As is the case for the U.S. agencies, the Canadian Forces do not offer standard definitions for many of the human-factor terms. The Defense and Civil Institute of Environmental Medicine published a report titled "Investigation of Human Factors in Aircraft Incidents and Accidents" (1975) which defines some of the terms but leaves the bulk of them undefined.

After a mishap investigation is completed, the investigating team prepares a final report which summarizes the mishap, presents suspected causes, and makes recommendations as to how similar mishaps could be prevented. In the RAF, the board's conclusions and recommendations are final. In the other services, the investigating team's conclusion and recommendations are subject to review and change by higher authorities.

Evaluation--A glaring weakness in most mishap investigations is the absence of standard definitions of the human factors involved in mishaps. The absence of these definitions creates an ambiguous situation, where the mishap investigator must not only try to determine what set of conditions led to a mishap but also to decide which human-factor labels (e.g., channelized attention, distraction, etc.) best describe that set of conditions. With no standard definitions, different investigators are apt to attach different definitions to a number of the human factors. When this happens, the findings from the different investigations will not be comparable.

A second problem with many mishap investigations is that the flight surgeons do not always possess the requisite human-factor expertise to assess the pilot factors involved in a mishap. In such instances, the findings from the investigation may be invalid.

Another problem is that the flight surgeon must investigate not only the human-factor causes of the mishap but also the causes and extent of injuries and the egress and life support that were involved in the mishap. This can be a great deal of work for one person to accomplish, so some parts of an investigation may receive less attention than others.

The human-factor portion of mishap investigations focuses (perhaps overly focuses) on pilot factors that occur in the cockpit. Investigations look for factors such as channelized attention or distraction, which may directly cause a mishap. They pay less attention to antecedent factors (which occur before the pilot enters the cockpit) that may precipitate situational factors (factors that occur in the cockpit). The RAF investigators, in contrast, carefully examine a pilot's flight-experience records, personal life history, and other preflight factors that may precipitate mishap-causing factors in the cockpit. The Navy, as mentioned previously, has begun to look at a pilot's personal life stress in an attempt to pinpoint preflight factors that lead to mishaps.

Another potential problem with many mishap investigations is that the final judgment as to the pilot (and nonpilot) factors involved in the mishap is made not by the investigators, but by a higher reviewing authority. This

authority reviews the investigative board's report of the mishap and formulates its own conclusions about the causes of the mishap and recommendations for preventing similar mishaps in the future.

Since investigative boards may have little investigative experience, the reviewing authority (which presumably reviews a number of mishaps) brings experience to the process and may be able to correct mistakes made by the local investigative board. Different investigative teams, however, do not always provide the same type of information in the same amount of detail in their reports. As a result, reviewing authorities not only may have invalid information to review, they may have incomplete information; thus, the review process has the potential to add even more error to a poorly written investigation report.

The RAF tries to avoid this problem by using central investigative boards. These boards investigate numerous mishaps and therefore have a great deal of expertise. These boards are given the final authority for determining mishap causes and recommending strategies to avoid similar mishaps. Such a review strategy, however, could become very expensive for an investigative agency such as the U.S. Air Force if it were charged with investigating mishaps around the world.

In sum, the major deficiency in the human-factor portion of many investigative programs is lack of consistency among mishap investigations. This results from the absence of standard definitions of terms, unequal abilities of investigators, and a lack of standard investigative procedures.

Recommendation--The most pressing need for the human-factor portion of Air Force mishap investigation programs is to establish a systematic, standard data collection procedure. Foremost in this task is to establish standard definitions of the human-factor information to be gathered. The use of standard definitions will increase the reliability and validity of information obtained from these investigations.

A second step is to provide trained human-factor specialists as part of the investigation team. These specialists could provide a valuable contribution by identifying the human factors involved in mishaps and by freeing the flight surgeon to concentrate on other parts of the investigation.

If human-factor specialists cannot be provided because of funding or other constraints, flight surgeons should be given more rigorous human-factor training. Moreover, the investigation task could be made easier and more standard by development of a systematic investigation procedure for determining the human factors involved in a mishap. The procedure would include strategies both for determining the situational factors which lead directly to the mishap and for tracing these situational factors back to antecedent causes. The Army has initiated such a system (see U.S. Army Aviation Digest, p.10, Dec 1977, and Army Regulation 95-5, 1975). The new investigation procedures could be augmented by development of a workbook or checklist which all human-factor investigators would study and use during the course of a mishap investigation.

A standardized investigation process would lead to comparability across investigations. Similar information would be available from each investigation, and the meanings of terms would be the same. Under these conditions, the review process would be more meaningful because the reviewers would have reliable and valid information to examine.

Analysis of an Aircraft Data Base

Twelve major factors were identified in the literature review on pilot factors involved in aircraft mishaps. Since the various articles reviewed did not use the same definitions of the pilot factors, we have proposed standard definitions.

The purpose of the effort described in this section was to systematically analyze recent Air Force aircraft mishap reports, using the standard definitions. This refined method of identifying the major pilot factors involved in mishaps will provide reliability to our identification of investigative areas. Access to mishap investigation reports was provided by the U.S. Air Force Inspection and Safety Center, Norton AFB, California.

Data and Method--A human-factor team was used to review mishap reports and identify pilot factors involved in the mishaps. To maximize the reliability and validity of their judgments, the researchers operated under the following conditions. First, instead of searching for a wide variety of pilot-factor causes, such as the many contained on the Air Force flight form, they focused on the 12 factors that were suggested by previous literature (including previous examinations of Air Force mishap reports) as the most important. Second, the team operated within the framework of standard conceptual and/or operational definitions for each of these factors. Third, the researchers attempted to be exhaustive in their investigations. They recorded all available information that would help identify what took place to bring about the mishaps. Fourth, the researchers used a standard coding form to guide their examination of the mishap reports. A copy of this coding form is contained in Appendix B as Exhibit B-1.

The coding form was developed after careful review of both the aircraft mishap literature and sample Air Force mishap reports. The form was designed to key the researchers to look for and record all available information that could help identify pilot factors that lead to mishaps. The coding form contains both pilot-factor variables that could be instrumental in the mishap and nonpilot factors such as weather conditions, flight profile, and condition and functioning of the aircraft. These nonpilot factors may interact with the pilot factors to produce a mishap. The coding key also includes aircraft type, date of accident, number of fatalities, and the cost of the mishap.

Channelized attention, disorientation/vertigo, distraction, panic, workload, and stress were measured by the researchers as potential causal factors in the mishaps viewed. Two personality characteristics--excessive motivation to succeed and overconfidence--were also used, as well as four discipline-related factors--nonobservance of mission rules, directives, air discipline, and established procedures.

Pilot's age was calculated from date of birth. Pilot's physical condition was measured by the flight surgeon's statement or description of the condition, and was coded as "good," "fair," or "poor." Fatigue was measured in the following three ways:

Hours slept in the past 24 and 48 hours

Hours worked in the past 24 and 48 hours, and

The length of the flight, including time in the cockpit prior to the flight.

Flight experience was assessed by the following variables:

Hours flown in the previous 24 and 48 hours

Numbers of sorties flown in the previous 24 and 48 hours

Numbers of sorties flown in the previous 30 and 60 days

Total sorties flown in the mishap aircraft type

Previous number of similar missions

Days since last flight

Days since last flight in the mishap aircraft type

Total flying hours

Total flying hours as a first pilot

Total flying hours in a jet aircraft

Total hours flown in the mishap aircraft type

Total weather instrument hours

Pilot rating.

No arbitrary standards were developed to designate when a pilot is fatigued or not fatigued or when he possesses sufficient experience; no such accepted levels exist. Hartman et al. (21), for example, were unable to observe a relationship between sleep levels and self-reports of fatigue. The best way to measure the effects of indicators of experience and fatigue would be to examine samples of both mishap and nonmishap flights. The strategy would be to measure the pilots' levels on the fatigue and experience indicators for both samples and see if significant differences existed.

Since nonmishap flight data are not available, an alternative strategy was used here. The indicators of fatigue and experience are variables that occur prior to a flight. As such, they do not directly "cause" a mishap, but may lead a pilot to perform or fail to perform in a manner that results in a

mishap. Hence, the strategy used here to indicate the effect of fatigue and experience on the occurrence of pilot-factor mishaps was as follows. First, the judgment was made as to which pilot factors (other than fatigue and experience) had a major influence on the mishap. Second, the indicators of fatigue and experience were correlated with these pilot factors to determine whether or not they were associated statistically.

The time period selected was January 1, 1977 through December 1978. This period was selected for two reasons. First, it is a period during which aircraft mishaps increased over previous rates (Directorate of Aerospace Safety, 1b). Second, beginning with January 1977, the mishap-reporting procedure was improved somewhat over past practices.

The sample of mishaps was selected from all attack, fighter, or trainer aircraft mishaps that were classified as resulting exclusively or partly from a pilot-related factor. The population was narrowed by selecting only Class A and Class B mishaps for which complete, or nearly complete, data were available in the investigation report. Class C mishaps were not included since these reports contained limited information. Class A mishaps are defined as those in which damage to the aircraft exceeds \$250,000 and/or there is a fatality. Class B mishaps range in cost from \$100,000 to \$250,000. Class C mishaps involve damage of less than \$100,000.

From the population, 70 mishap reports were sampled. This sample size was chosen, on the basis of a standard statistical power analysis, as the number of cases needed to calculate the Return-on-Investment Metric (ROI).

The sample consists of 65 Class A mishaps and five Class B mishaps. The 65 Class A mishaps involved a human factor and represent 84% of all Class A mishaps that occurred during 1977-78. The five Class B mishaps represent only 10% of all Class B human-factor mishaps, but 100% of the Class B human-factor mishaps that had complete or nearly complete mishap reports. Table 3 indicates the aircraft types contained in the sample.

The 70 reports were read by a two person research team. Each person read approximately 35 reports. In many instances, the data were recorded by copying the information directly from the appropriate form in the mishap report; e.g., weather conditions and many of the pilot-experience and fatigue measures. The operation or failure of any of the aircraft components was taken directly from the board's judgment as to the status of the component.

The researchers were required to make decisions about the presence or absence of several pilot-factor items. To do this, they read the narrative description of the mishap and judged whether any of these factors were present. In making their decision, the researchers were guided by the definitions of these factors presented on pages 25 and 26.

The researchers were told not to make any judgments about the causal nature of these factors, but simply to code whether the factors were present or not present in the mishap. The narratives often do not contain enough detailed information to make a judgment as to the causal nature of each factor. The assumption was made that if a factor with the potential to cause a mishap (such as those examined here) was present in a large number of mishaps, it could be inferred to be a causal factor.

TABLE 3. TYPE OF AIRCRAFT SAMPLED

<u>Type</u>	<u>No. Sampled</u>	<u>Type</u>	<u>No. Sampled</u>
AFD	6	F105D	2
A10A	5	F105G	2
F4C	1	F106A	3
RF4C	6	F106B	1
F4D	7	F111A	1
F4E	4	F111D	2
F5E	3	F111E	1
F15A	4	F111F	3
F15B	1	FB111A	2
F100D	5	T33A	1
F109F	3	T37B	2
		T38A	5

The inference to causality would be stronger if data were available on nonmishaps. If a factor occurs frequently during mishaps but infrequently during nonmishaps and if the factor can theoretically be shown to be able to cause a mishap, then inferring causality is appropriate. Nonmishap data, however, are not available. Therefore, inferred causality was based only on the frequency of occurrence of a factor in mishaps and on the theoretical rationale that the factor could cause a mishap.

After making a decision about the presence or absence of these factors, the researchers were instructed to note the investigative board's conclusions as to which psychophysiological human factors were present in the mishap. This information was taken from Form 711GA (Exhibit B-3) only after the researchers had made their own judgments. The reason for instructing the researchers to make their judgments independently of the official investigative board was to allow for comparison between the two sets of judgments. These comparisons form the basis for determining the reliability of the findings.

Major pilot factors involved in aircraft mishaps are those factors that occur most frequently concomitant with a mishap. Table 4 presents the factors that either the BDM researchers or the Air Force investigators judged to occur in more than 10% (8 or more) of the 70 mishaps studied. The table shows a general agreement among the two sets of coders concerning the first four factors.

Both groups rated channelized attention as the major pilot factor associated with mishaps. The Air Force investigators judged channelized attention to occur in 54% of the mishaps. Distraction was the second most observed factor; disorientation/vertigo, third; and excessive motivation to succeed,

TABLE 4. MAJOR PILOT FACTORS ASSOCIATED WITH AIRCRAFT MISHAPS

<u>Factor</u>	<u>BOM Coding</u>	<u>Air Force Coding</u>
Channelized Attention	32 (46%)	33 (54%)
Distraction	26 (37%)	21 (30%)
Disorientation/Vertigo	22 (31%)	17 (24%)
Excessive Motivation to Succeed	14 (20%)	15 (23%)
Overconfidence	13 (19%)	5 (11%)
Stress	13 (19%)	a
Apprehension	a	10 (14%)
Visual Illusion	a	6 (11%)

aDid not evaluate this factor

fourth. The contract researchers judged overconfidence and stress each to occur in 13 mishaps, making them a tie for the fifth most frequent pilot factor. The Air Force investigators ranked apprehension as the fifth most frequent factor, with overconfidence and visual illusion tied as the sixth.

Although the contract researchers did not attempt to judge the occurrence of fatigue, the Air Force investigators did and judged it not to be a major factor. Fatigue based on sleep deprivation was judged to occur in only 5 (7%) of the mishaps, while "other fatigue" was judged to occur in only 2 (3%) of the mishaps.

The results of correlating the indicators of fatigue and experience with the eight major pilot factors did not yield a strong relationship. Hours slept during the previous 24 hours had only a slight relationship to apprehension and visual illusion, with correlations of .22 and .29 respectively. Total first-pilot hours had a slight negative relationship with distraction, with a correlation of -.30.

No other significant correlations were seen between any of the eight major pilot factors and the indicators of fatigue and experience. As a result, fatigue and experience were not judged to be major pilot factors involved for this sample of 70 mishaps.

Reliability of the Data--The fact that BOM researchers and the Air Force investigators closely agreed in their judgments of pilot factors suggests a degree of reliability in the data. Table 5 presents the correspondence between the two groups for five of the eight major pilot factors that they both coded. The percent agreement reported below each factor is obtained by dividing the total number of mishaps for which the coders agreed (the sum of the diagonal elements "no-no" and "yes-yes") by the total number of mishaps (70). As can be seen, coder agreement ranges from 60% (channelized attention)

TABLE 5. CORRESPONDENCE BETWEEN BDM AND AIR FORCE PILOT-FACTOR CODES

CHANNELIZED ATTENTION

		AF CODE	
		NO	YES
BDM CODE	NO	21	17
	YES	11	21

PERCENT AGREE = 60

DISTRACTION

		AF CODE	
		NO	YES
BDM CODE	NO	35	9
	YES	14	12

PERCENT AGREE = 67

DISORIENTATION/VERTIGO

		AF CODE	
		NO	YES
BDM CODE	NO	42	6
	YES	11	11

PERCENT AGREE = 75

OVERCONFIDENCE

		AF CODE	
		NO	YES
BDM CODE	NO	55	2
	YES	7	6

PERCENT AGREE = 87

SUCCESS MOTIVATION

		AF CODE	
		NO	YES
BDM CODE	NO	43	10
	YES	8	6

PERCENT AGREE = 77

to 87% (overconfidence). The overall coder agreement is 73%. This figure is obtained by summing the total number of mishaps for which the coders agreed for each of the five pilot factors, then dividing by 350. While that agreement is acceptable by social science standards, much of the agreement stems from the fact that the coders tend to agree when a factor is not present. The highest entry in each of the tables occurs in the "no-no" cell.

Another method for considering reliability is to look only at instances where either set of coders identifies one factor as present and then to determine the degree of agreement between the coders. To do this requires eliminating the "no-no" cell and recalculating the reliabilities. This is done by calculating the total number of mishaps for which the coders agreed and dividing by the total number of observations in the table. Table 6 summarizes these operations; the reliability ranges from 25% (success motivation) to 43% (channelized attention), and the overall coder agreement for all five factors is 37%.

Discussion--The consensus of both the BDM researchers and the Air Force investigators is that channelized attention, distraction, disorientation/vertigo, and excessive motivation to succeed are the four factors most frequently involved in aircraft mishaps. Other major factors identified by either set of coders are overconfidence, stress, apprehension, and visual illusion.

A careful analysis of these factors shows that they can be divided into two categories: predispositional and situational. Overconfidence and excessive motivation to succeed are conditions within the pilot which he brings to a flight and which can predispose him to perform or fail to perform some activity, with this performance or nonperformance leading to a mishap. For example, a pilot overly motivated by success may attempt to acquire a target on his first pass even though he cannot adequately control the aircraft during the pass. As a result, he may fail to recover during target acquisition, and crash.

Channelized attention, distraction, disorientation/vertigo, visual illusion, stress (as defined here), and apprehension are typically situational factors, which, when they occur, delay the pilot from making a critical response. In an aircraft these situational factors become critical because the pilot's time to respond to demands is brief. The time-compressed information-processing nature of the pilot's task is the factor that renders these situational pilot factors problematic. Any time one of these factors occurs, it can interfere with information processing and lead to a mishap.

This point deserves some further amplification. A pilot is sometimes referred to as a mission manager. Essentially, he processes a wealth of information and performs appropriate responses. The bulk of mishaps related to pilot factors may occur because the pilot is frequently pushed to his information-processing limits, and then minor disturbances such as distraction can lead to mishaps. If this is true, studying time-compressed information processing may lead to ways to identify a pilot's maximum information-processing capabilities, reduce the information-processing demands of the more difficult piloting tasks, and/or increase the pilot's ability to process information. Each of these findings could help reduce pilot-factor mishaps.

TABLE 6. CORRESPONDENCE BETWEEN BDM AND AIR FORCE CODERS FOR OCCURRENCE OF PILOT FACTORS

CHANNELIZED ATTENTION

BDM CODE	AF CODE	
	NO	YES
NO	X	17
YES	11	21

PERCENT AGREE = 43

DISTRACTION

BDM CODE	AF CODE	
	NO	YES
NO	X	9
YES	14	12

PERCENT AGREE = 33

DISORIENTATION/VERTIGO

BDM CODE	AF CODE	
	NO	YES
NO	X	6
YES	11	11

PERCENT AGREE = 41

OVERCONFIDENCE

BDM CODE	AF CODE	
	NO	YES
NO	X	2
YES	7	6

PERCENT AGREE = 40

SUCCESS MOTIVATION

BDM CODE	AF CODE	
	NO	YES
NO	X	10
YES	8	6

PERCENT AGREE = 25

At other times, time-compressed information processing is not really the mishap cause. For example, a pilot may be involved in a low-level bombing mission. He may be in perfect control of the aircraft with no information-processing problems at all. He may, for some reason, become fascinated with the trace of the bombs on the target and simply forget to pull out of a dive, and crash. In this scenario, the pilot is not pushed to his information-processing limits. His mind is taken off his mission for some unknown reason. Clearly, more information is required as to how these situational factors come about. With such information, finding common elements underlying pilot-factor mishaps could aid in discovering remedies for these mishaps.

While the coders tend to agree about the rank ordering of the major pilot factors, the intercoder reliability between the Air Force and BDM investigators suggests that the two groups may have had different notions about the meaning of terms. The coders tend to agree when the phenomena are absent, as indicated by the high "no-no" value in the reliability tables; however, when the factors are present, the coders tend to disagree as to the labels to attach to the factors.

An obvious reason for this disagreement is the lack of a common definition for each pilot factor. While the BDM researchers worked with the definitions presented at the beginning of this section, the Air Force investigators did not necessarily use the same definitions. As a matter of fact, since a number of Air Force investigators were involved in coding these 70 mishaps and since the Air Force does not provide investigators with a common set of definitions, the Air Force investigators themselves were possibly not operating under a common set of definitions. Another reason for the absence of higher degrees of reliability is that judgment of the presence of a pilot factor is often based on the very limited and incomplete information available after the mishap.

Recommendations--A consistent theme throughout this section has been the lack of reliability in mishap investigations due to the absence of standard definitions of pilot factors involved in mishaps. Therefore, we recommend that the Air Force develop such standard definitions and provide them to all human-factor investigators.

Second, we recommend that the Air Force initiate the investigation of near-mishaps. In such investigations, Air Force safety personnel will be able to interview pilots to find out specifically what occurred in the cockpit to produce the near-mishaps.

A final recommendation is that the Air Force develop a computerized database to house investigation reports. This information could be made available to researchers to explore various dimensions of the pilot-factor issue.

Summary

The purpose of this section was to identify the major pilot factors involved in aircraft mishaps. The first step was to review recent aircraft-mishap literature to develop an idea of pilot factors that contribute to mishaps. The second step was to review the process by which several safety

agencies examine pilot-factor mishaps. Equipped with this information, a BDM research team examined 70 recent Air Force aircraft mishaps involving a pilot factor. These researchers were given standard definitions of a number of potential pilot factors contributing to mishaps. They read mishap investigation narratives and, using the defined terms, judged the pilot factors present in the mishap. The researchers were aided in their task by a detailed coding sheet that cataloged the specific information they were instructed to collect.

The BDM researchers also recorded the pilot factors that Air Force investigations had judged to be present in these mishaps; generally the two groups agreed as to the major pilot factors involved. The BDM researchers uncovered six factors that occurred in more than 10% of the mishaps. The Air Force uncovered seven such factors, five of which overlapped with the BDM researchers' findings.

The following eight factors were judged by either the Air Force or the BDM team to be present in more than 10% of the mishaps. The parenthetic entry indicates whether the factor was judged important by the BDM researchers, the Air Force investigators, or both.

- (1) Channelized Attention (both)
- (2) Distraction (both)
- (3) Disorientation/Vertigo (both)
- (4) Excessive Motivation To Succeed (both)
- (5) Overconfidence (both)
- (6) Stress (BDM)
- (7) Apprehension (Air Force)
- (8) Visual Illusions (Air Force)

III. INVESTIGATIVE AREAS RANK ORDERED IN RELATION TO A RETURN-ON-INVESTMENT METRIC

The previous section identified eight pilot factors present in more than 10% of selected pilot-factor mishaps occurring in 1977-78 and involving fighter, attack, or trainer aircraft. The purpose of this section is to list these factors in the order in which they should be investigated. This priority list will be based on the expected return-on-investment (ROI) that a reduction of mishaps due to these causes can be anticipated to produce.

This objective was accomplished by

- (1) developing an ROI metric based on the dollar cost of various mishaps,
- (2) applying the ROI metric to the major pilot factors involved in aircraft mishaps, and
- (3) rank ordering these pilot factors in regard to the ROI metric.

Developing the ROI Metric

A return-on-investment metric is a tool for estimating the dollar savings from mishap reduction to be realized by undertaking various levels of research into specific factors present in mishaps. An ROI metric can be depicted with the following formula:

$$\text{ROI} = \text{Total Dollar Saving} - \text{Total Dollar Research Cost} \quad (1)$$

That is, the return on investment is the difference between how much was saved and how much was spent to obtain that saving. To obtain an ROI based on research into pilot factors, estimates are needed for both the cost of pilot-factor research and the total dollar savings to be realized by such research.

For purposes of this report, costs of pilot-factor research projects are fixed at 2, 3, and 5 manyears. Consequently, taking total research dollar cost in Formula 1 to be fixed, the ROI requires that the total dollar saving be estimated.

The maximum dollar saving possible from research into any pilot factor is the total amount of money that factor costs the Air Force. The total dollar saving will be the percentage of the total cost associated with a pilot factor that can be eliminated (or reduced) by research into that factor. This can be depicted by the following formula:

$$\text{Total Dollar Saving} = \text{Total Dollar Cost} \times \text{Percentage Mishap Reduction} \quad (2)$$

For example, suppose pilot-factor X was associated with \$100 million worth of damage. If research could lead to elimination of 20% of these mishaps, the dollar saving to be realized by research into pilot-factor X would be approximately \$100 million \times .20, or \$20 million.

The total dollar cost associated with a particular pilot factor can be estimated from data on previous mishaps. Estimates of how effective research will be, however, are not so straightforward. One reason is that the ultimate research effectiveness will be based on intangibles such as the research team personnel and their access to and use of relevant facilities and materials.

A possible predictor of how effective this research into a specific pilot factor will be is how effective previous research has been. The literature will be reviewed to determine the state of investigation for each major pilot factor. If the literature review for a particular pilot factor shows a well-integrated body of research with positive results, and prospects for even more positive results, then future research should be effective. Alternatively, if the state of the literature is disorganized and indicates little if any positive results, then effectiveness of future research would be difficult to predict.

Knowing the antecedent conditions (if any) which led to a pilot factor would help in estimating the potential effectiveness of research into eliminating mishaps due to that factor. If the factor itself cannot be directly eliminated, it might be indirectly eliminated by modifying the antecedent factors that cause it to occur.

The approach for calculating the ROI metric will be, first, to identify the major pilot factors involved in aircraft mishaps. Then the total dollar cost in terms of aircraft damage associated with each factor will be estimated. Next, an attempt will be made to identify the antecedent conditions that help to bring about the pilot factors.

Finally, a review of the literature will be conducted. Each pilot factor and its antecedent causes will be reviewed. Based on this review, a judgment will be made as to how effective the research into each pilot factor will be. This information along with the total dollar cost associated with each pilot factor will be entered into Formula 2, and the total dollar-saving parameter will be estimated.

Applying the ROI Metric

This section describes, first, the data used to identify the major pilot factors; second, the major pilot factors involved in mishaps and the total and average dollar costs associated with each pilot factor; third, the antecedent causes of these pilot factors; and fourth, an estimate of research effectiveness in regard to the specific pilot-factor areas.

Data--For identifying the pilot factors, data were taken from 70 aircraft mishap reports made available by the Air Force Inspection and Safety Center, Norton AFB, California. The 70 mishaps were randomly selected from the population of pilot-factor mishaps that took place in 1977-78 and involved an attack, fighter, or trainer aircraft. The data were obtained by two BDI researchers who read through the mishap reports and coded pertinent information on coding sheets such as the one in Appendix B (Exhibit B-1).

The researchers read the narrative of each mishap and made their own judgment as to the pilot factor involved; specific definitions of a number of pilot factors were provided to guide their judgments. Then, to provide a reliability check on their judgment, the researchers also recorded the pilot factors judged by Air Force investigators of the mishaps to be involved. Section II contains a more detailed description of the data and method in which the data were acquired.

Major Pilot Factors Involved in Aircraft Mishaps--The major pilot factors involved in fighter, attack, and trainer Air Force aircraft were identified from the 70 mishap reports reviewed by the researchers. The BDM research team uncovered six pilot factors that were involved in more than 10% (8 or more) of the mishaps.

In general, the BDM researchers and the Air Force investigators agreed upon the major pilot factors involved in these 70 mishaps (see Table 4, page 35). Both groups rated channelized attention as the major pilot factor. The Air Force investigators judged channelized attention as occurring in 54% of the mishaps; the BDM researchers, in 46%. Distraction was the second most observed factor; disorientation/vertigo, third; and excessive motivation to succeed, fourth. BDM researchers found overconfidence and stress in 13 mishaps, placing them fifth. The Air Force investigators ranked apprehension as the fifth most frequent factor, with overconfidence and visual illusion tied for sixth place.

Part of the disagreement between the findings of the BDM researchers and Air Force investigators may lie in the fact that the Air Force does not provide its investigators with standard definitions of pilot-factor variables; thus, the two groups may well have had different conceptions of the same factor.

The BDM researchers used the following definitions for the major factors they uncovered:

- Channelized Attention - A behavioral phenomenon that occurs when a pilot's full attention is focused on one stimulus to the exclusion of all others. This becomes a problem when the pilot fails to perform tasks or process information of a higher or more immediate priority and thus fails to notice or has no time to respond to cues of impending disaster.

- Disorientation - A loss of one's place-in-space that occurs when a pilot's perception of the aircraft's attitude or motion is incongruent with respect to Earth. This is due to inadequate sensory stimuli, an incorrect interpretation of sensory stimuli due to limitations in sensory receptors, incorrect selection of competing stimuli, or the absence of a general cognitive framework that realistically orients the operator within his environment.

- Vertigo - A form of physiological disorientation that occurs when a pilot senses that he or the external world is rotating. Any form of disorientation becomes a problem when a pilot is not cognizant of being disoriented and responds according to his incorrect appraisal of the situation, or when the pilot is cognizant of being disoriented but is unable or does not have enough time to correctly reorient himself while tending to other vital flying tasks.

- Distraction - A behavioral phenomenon that occurs when a pilot's focus of attention on flying tasks is interrupted by a stimulus unrelated to those tasks. This becomes a problem when the pilot fails to refocus attention on flying tasks of a higher or more immediate priority in time to recognize and respond to cues of impending disaster.

- Excessive Motivation To Succeed - A personality characteristic that predisposes a pilot to set unrealistically high standards for himself and try to perform tasks for which he is knowingly ill-prepared. This becomes a problem when mission success is afforded a higher priority than caution, judgment, or known restrictions.

- Overconfidence - A personality characteristic that a pilot may develop with experience or with positive reinforcement during training. It predisposes the pilot to overestimate personal ability, the ability of others, and/or the ability of the aircraft. It becomes a problem when the pilot attempts to perform tasks that exceed personal or aircraft capabilities.

- Stress - A heightened psychophysiological response state experienced when a pilot perceives that the workload demands of the flight may exceed his capabilities and that the successful completion of the flight is thus threatened. In such a situation, the pilot's adaptive mechanisms become severely taxed. Problems arise when his adaptive mechanisms are taxed to the point that they collapse and the pilot is unable to meet the workload demands of the flight.

The dollar cost associated with each major pilot factor was obtained by determining the damage to the aircraft and to the equipment on the aircraft. No dollar estimates were attached to the loss of lives or the resulting loss of combat effectiveness and training costs since such values are almost impossible to calculate.

Table 7 presents the total and average dollar costs associated with each major pilot factor. The costs are presented separately for the BDM and the Air Force codings. The total dollar costs associated with the mishaps vary widely. The most costly factors are channelized attention, distraction, disorientation/vertigo, and excessive motivation to succeed. The Air Force coding finds overconfidence involved in \$14.5 million, and channelized attention in nearly \$200 million.

The average dollar cost per mishap also varies. For the BDM-coded mishaps, channelized-attention mishaps tend to cost, on the average, more than twice as much as the stress-related mishaps. For the Air-Force-coded mishaps, distraction-related mishaps cost more than three times as much as overconfidence mishaps.

Antecedent Causes of Major Pilot Factors--As noted previously, estimating the effectiveness of research to reduce or eliminate mishaps associated with the major pilot factors would be easier if we understood more clearly how these factors originate.

TABLE 7. TOTAL AND AVERAGE DOLLAR COSTS^a ASSOCIATED WITH EIGHT PILOT FACTORS

	BDM coding		U.S. Air Force coding		
	Mean	Total	Mean	Total	
Channelized attention	\$4.57	(32) ^b	\$146.3	\$5.23 (38)	\$198.9
Distraction	4.14	(26)	107.5	5.47 (21)	114.9
Disorientation/ Vertigo	3.29	(22)	72.4	5.49 (17)	93.4
Excessive motivation to succeed	3.85	(14)	54.0	4.48 (16)	71.6
Overconfidence	3.67	(13)	47.7	1.80 (8)	14.5
Stress	2.06	(13)	26.8	c	
Apprehension	c			4.81 (10)	48.1
Visual illusion	c			3.85 (8)	30.8

^aIn millions.

^bEntry in parentheses is number of mishaps for which factor was present.

^cThis factor was not evaluated. (See Section II.)

This section attempts to identify antecedent causes of these major pilot factors. The approach selected was to correlate the occurrence or nonoccurrence of each pilot factor with a host of both pilot-related and non-pilot-related factors. These factors were obtained from the mishap investigation reports and are contained in the coding key in Appendix B. The specific factors and their operational measurements are as follows.

1. Weather Conditions: The following variables representing weather and visibility conditions were coded 0 if the factor was absent and 1 if it was present.

- Clear
- Obscuration
- Cloud cover
- Turbulence
- Fog
- Rain
- Sleet

Snow
Thunderstorms
Tornadoes
Special warnings
Visibility--coded as the number of miles of visibility
Wind velocity--coded in knots

2. Aircraft History and Functioning During the Mission:

a. Aircraft History

Total flight hours - airframe
Total flight hours - engine
Hours since last airframe overhaul
Hours since last engine overhaul
Recently unscheduled maintenance: 0 = No
1 = Yes

b. Aircraft Functioning During Flight (Coded 0 if component/system was functioning properly during flight; 1 if defective)

Flight controls
Electrical system
Hydraulic system
Radio
Engine
Pneumatic system
Instrumentation
Navigation system
Other systems

3. Flight Profile (Coded 0 if condition was absent and 1 if present):

a. Phase of Flight

Takeoff
Climbout
Enroute
Range
Descent
Landing

b. Mission Element

Air-to-ground ordnance delivery
Low-level navigation: below 5000 ft (1500 m)
Low-level maneuvering: below 5000 ft
Air-to-air engagement
Maneuver with formation
Search and rescue
Acrobatics

c. Time of Day

Dusk
Dawn
Day
Night

d. Altitude when Mishap Sequence Began

4. Pilot Factors:

a. Fatigue

Hours worked during previous 24-hour period
Hours worked during previous 48-hour period
Hours slept previous 24-hour period
Hours slept previous 48-hour period
Hours continuous duty prior to flight
Time in cockpit prior to flight
Length of flight

b. Experience

Hours flown in previous 24 and 48 hours
Number of sorties flown in previous 24 and 48 hours
Number of sorties flown in previous 30 and 60 days
Total sorties flown in mishap aircraft type
Previous number of similar missions
Days since last flight
Days since last flight in mishap aircraft type
Total flying hours
Total flying hours as first pilot
Total flying hours in jet aircraft
Total hours flown in mishap aircraft type
Total weather-instrument hours
Pilot rating

c. Pilot's Age (years)

d. Pilot's Physical Condition (good, fair, poor)

e. Use of Alcohol or Drugs Prior to Flight: 0 = No
1 = Yes

Table 8 presents the results of the correlation analyses. The correlations presented are Pearson product moment correlations. The table shows that very few of the antecedent factors examined are related to the occurrence of the major pilot factors. Various elements of the mission, such as air-to-ground and air-to-air engagements, tend to be related to selected pilot factors. The strongest relationship is between disorientation/vertigo and clear weather. This relationship suggests that on clear days pilots have a tendency to become disoriented, perhaps because it is difficult to distinguish between the ground and the sky.

TABLE 8. ANTECEDENT FACTORS SIGNIFICANTLY RELATED TO MAJOR PILOT FACTORS

<u>Antecedent Factor</u>	<u>Pilot Factor</u>	<u>Correlation</u>
<u>Coded by BDM:</u>		
Air-to-air engagements	Channelized attention	.37
Air-to-ground engagements	Channelized attention	.29
Total first-pilot hours	Distraction	-.30
Clear weather	Disorientation/Vertigo	.70
Pilot's physical condition	Disorientation/Vertigo	.38
<u>Coded by U. S. Air Force:</u>		
Air-to-ground engagements	Channelized attention	.36
Low-level navigation	Channelized attention	.20
Air-to-ground engagements	Disorientation/Vertigo	.24
Air-to-ground engagements	Excessive motivation to succeed	.30
Hours slept previous 24	Apprehension	.22
Hours slept previous 24	Visual illusion	.29

Determining whether certain pilot-factor mishaps occurred in certain types of aircraft was not possible. Not enough data points were available to get an adequate sample of mishaps for each aircraft-type sampled.

Estimating the Effectiveness of Research To Reduce or Eliminate the Major Pilot Factors--The last information needed to calculate the ROI metric is an estimate of research effectiveness regarding the major pilot factors and its applicability to reducing or eliminating mishaps due to these factors. The approach we used was to scrutinize previous research that had attempted to determine remedies for the major pilot factors, assess its effectiveness, and estimate its cost.

This literature review is summarized here and reported more fully in Section IV. The most striking characteristic of this literature is the lack of systematization of the research it contains. No organized, programmatic attempts on a wide-scale to eliminate or reduce pilot factors are recorded. Only scattered and fragmented attempts have been made to diagnose pilot factors involved in mishaps and to suggest remedial solutions to these problems. Even when a remedial solution has been devised and implemented, it is not followed up by evaluation of the success or failure of the solution. The literature on previous research into the major pilot factors involved in mishaps appears to be inconclusive.

Based on the review of the literature regarding aviation technologies, and the current state of knowledge about the major pilot factors, no factor appears to be more or less resistant to investigation than any other factor.

Rank Ordering Pilot Factors in Terms of the ROI

This discussion will be confined to the six pilot factors identified by the BDM researchers. Because these researchers used standard definitions when making their judgments about the presence of pilot factors in mishaps, we can be more confident about what is meant by each of the factors named. The Air Force investigators were not guided by standard definitions, and we cannot be certain that they used the same meanings as BDM.

After investigating the ROI from reducing pilot-factor mishaps, we have no reason to believe that research into any of the six factors will be more or less successful than research into the other factors. Therefore, we can assume that each factor investigated, given the same level of research investment, would yield approximately the same percentage of mishap prevention. If we assume that percentage mishap reduction is fixed in Formula 2, then the more total dollar cost associated with a particular factor, the greater the total dollar saving to be anticipated by investigating that factor.

By this logic, the factors would be rank ordered on the ROI metric in the following manner:

- (1) Channelized attention
- (2) Distraction
- (3) Disorientation/Vertigo
- (4) Excessive motivation to succeed
- (5) Overconfidence
- (6) Stress

The average dollar cost associated with the 70 mishaps is \$3.82 million, so prevention of just one pilot-factor mishap would save an average of \$3.82 million, and in the case of fatal mishaps, a life. Given that the funding level of social science research projects is typically less than \$1 million, successful prevention of just one mishap will yield a substantial return on the research investment. We can, therefore, expect effective research into the major pilot factors to yield a sizable return on investment.

Discussion and Recommendations

The major recommendation arising from this section is that the largest return on the research investment would be realized by focusing on the pilot factor that costs the Air Force the most money; i.e., channelized attention. Other factors to investigate would be as rank ordered in terms of the ROI.

The review of available data and literature relating to investigative areas indicates that of the six major factors, four (channelized attention, distraction, disorientation/vertigo, and stress) occur in the cockpit during flight. We could not determine, however, exactly what occurs in the cockpit

to precipitate these factors; nor were we able to determine which antecedent factors, if any, occur before the pilot begins the flight, which may predispose him to be subject to the four major factors.

Any research that attempts to develop solutions to these major pilot factors will have to begin with a clear description of the scenario under which these factors occur. In an aircraft, channelized attention, distraction, disorientation/vertigo, and stress become critical because the pilot's time to respond to situational demands is brief: the time-compressed information-processing nature of the piloting task renders these situational pilot factors problematic. Anytime one of these factors occurs, it can interfere with information processing and lead to a mishap.

A pilot is sometimes referred to as a mission manager. Essentially he processes a wealth of information and performs appropriate responses. The bulk of mishaps related to pilot factors may occur because the pilot is frequently pushed to the limits of his information-processing capabilities, and then minor disturbances such as distractions lead to mishaps. If this is true, then studying time-compressed information processing may lead to ways to identify a pilot's maximum information-processing capabilities, reduce the information-processing demands of the more difficult piloting tasks, and/or increase the pilot's ability to process information. Each of these findings could help reduce pilot-factor mishaps.

We can also describe scenarios where time-compressed information processing is not the mishap cause. For example, a pilot may not be pushed to his information-processing limits; his mind may simply be distracted from his mission for some unknown reason.

More information is required as to how these situational factors come about. With such information, we may discover commonalities underlying pilot-factor mishaps. Finding such common elements could aid in discovering remedies for the mishaps.

The lack of more precise information about the major pilot factors is due partly to the nature of the major source of data about these factors, mishap investigation reports. Two deficiencies can be identified in the investigation process. First, the investigators don't have standard definitions of the human-factor terms that are used to label mishap causes. Second, the human-factor investigators are not always well enough trained to "dig into" the mishap to determine specifically what went on in the cockpit prior to the mishap or what preflight factor may have led to the mishap.

Another problem, unrelated to the investigation process per se, is that much of the information needed to determine what occurred in the cockpit prior to the mishap can be obtained only from the pilot, who is frequently a fatality.

Since mishap investigations provide an inadequate source of data, three changes to the investigation process are recommended. First, human-factor investigators should be given standard definitions of pilot factors that may be involved in aircraft mishaps. This will provide reliability among investigators. Second, the investigators should be trained to explore mishaps more

carefully in order to search for other factors that may influence the occurrence of the major pilot factors. Third, the Air Force should consider investigating near-mishaps. By these, investigators would be able to interview the pilot to find out specifically what occurred in the cockpit to produce the near-mishap.

Before concluding this section, one caveat should be put forward. The ROI was calculated based on the assumption that the pilot factors most frequently occurring in a mishap are the most important pilot-factor "causes" of mishaps. This inference to causality was based not only on the frequency with which these factors occur, but also on the theoretical assumption that these factors are indeed capable of causing a mishap. The inference of causality would be even stronger if data were available concerning nonmishap flights.

If a pilot factor is truly a "cause" of a mishap, it would occur primarily during mishaps but not during nonmishap flights. However, nonmishap data are not available, so we were unable to see how frequently the major pilot factors occurred in nonmishap flights. We tried to overcome this drawback by a statistical technique involving regression analysis, but this was unsuccessful. Some information on successful flights would be useful in the overall process of identifying pilot factors involved in aircraft mishaps.

Summary

The purpose of this section was to rank order six pilot factors, judged by a BDM research team to be major factors in mishaps, in terms of the dollar savings in mishap reduction to be realized by research into each factor.

The first step was to determine the total dollar cost associated with mishaps occurring from each of these factors. The next step was to determine how effective research into each area would be. This was done by reviewing previous studies that attempted to reduce or eliminate aircraft mishaps due to these factors. This literature review indicated that no one pilot-factor area is more amenable to effective research than any other area.

We concluded, therefore, that if research were conducted into specific pilot factors, the return on investment of this research would be proportional to the dollar cost associated with each of the factors. Therefore, the six pilot factors identified by the BDM researchers were rank ordered in terms of anticipated return on investment.

IV. HUMAN-FACTOR AVIATION TECHNOLOGIES

The purpose of this section is to identify and describe human-factor technologies in aviation that are applicable to the prevention of pilot-factor mishaps. We will review some inputs of Section II to define pilot factors in mishaps, list aviation/human-factor technologies previously applied to mishap prevention by article, and select most promising technologies available with regard to the major pilot factors.

Here technology is defined as a research procedure designed to establish causal relationships between selected pilot factors and aircraft mishaps. Hard technologies include actual machines that augment human performance, such as simulators and instrument warning systems. Soft technologies include behavioral techniques such as questionnaires and stress indices to study human problems.

The interrelationship between the hard and soft technologies is important in studying pilot factors in aircraft mishaps. For example, using a hard technology such as the NASA/Langley Visual Motion Simulator (VMS) in a laboratory environment to familiarize the pilot with the sensation of disorientation is an important methodology. Equally important is using the workload opinion questionnaire to identify the pilot's problems. Both technologies can provide the Air Force with data to help eliminate mishaps.

Major Pilot Factors Involved in Aircraft Mishaps

A team of researchers examined a sample of 70 aircraft mishap investigations attributed partly or wholly to a pilot-factor cause. These mishaps represented 85% of all pilot-factor mishaps for the period 1977-78 and included fighter, attack, and trainer aircraft. The researchers read through the mishap reports and coded pertinent information about the mishap on coding sheets such as that appearing in Appendix B.

To guide their judgments, the researchers were given specific definitions of a number of pilot factors. Also, to provide a reliability check on their judgments, the researchers were instructed to record the pilot factors that the Air Force investigators of the mishap had judged to be involved. Section II describes more fully the method in which the data were acquired.

The results of this analysis yielded eight pilot factors that appeared in more than 10% of the mishaps examined. These included apprehension, channelized attention, disorientation/vertigo, distraction, excessive motivation to succeed, overconfidence, stress, and visual illusion.

These pilot factors are defined as follows:

- Apprehension - A psychosocial phenomenon that results from the anxious anticipation of a flight mission by the pilot. This becomes a problem when the pilot's apprehension precludes his concentration on vital flight tasks.

- Channelized Attention - A behavioral phenomenon that occurs when a pilot's full attention is focused on one stimulus to the exclusion of all others. This becomes a problem when the pilot fails to perform tasks or process information of a higher or more immediate priority and thus fails to notice or has no time to respond to cues of impending disaster.

- Disorientation - A loss of one's place-in-space that occurs when a pilot's perception of the aircraft's attitude or motion is incongruent with respect to Earth. This is due to inadequate sensory stimuli, an incorrect interpretation of sensory stimuli due to limitations in sensory receptors, incorrect selection of competing stimuli, or the absence of a general cognitive framework that realistically orients the operator within his environment.

- Vertigo - A form of physiological disorientation that occurs when a pilot senses that he or the external world is rotating. Any form of disorientation becomes a problem when a pilot is not aware of being disoriented and responds according to his incorrect appraisal of the situation, or when the pilot is aware of being disoriented but is unable or does not have enough time to correctly reorient himself while tending to other vital flying tasks.

- Distraction - A behavioral phenomenon that occurs when a pilot's focus of attention on flying tasks is interrupted by a stimulus unrelated to those tasks. This becomes a problem when the pilot fails to refocus attention on flying tasks of higher or more immediate priority in time to recognize and respond to cues of impending disaster.

- Excessive Motivation To Succeed - A personality characteristic that predisposes a pilot to set unrealistically high standards for himself and to try to perform tasks for which he is knowingly ill-prepared. This becomes a problem when mission success is afforded a higher priority than caution, judgment, or known restrictions.

- Overconfidence - A personality characteristic that a pilot may develop with experience or with positive reinforcement during training. It predisposes the pilot to overestimate personal ability, the ability of others, and/or the ability of the aircraft. It becomes a problem when the pilot attempts to perform tasks that exceed personal or aircraft capabilities.

- Stress - A heightened psychophysiological response state experienced when a pilot perceives that the workload demands of the flight may exceed his capabilities and that the successful completion of the flight is thus threatened. In such a situation, the pilot's adaptive mechanisms become severely taxed. Problems arise when his adaptive mechanisms are taxed to the point that they collapse and the pilot is unable to meet the workload demands of the flight.

- Visual Illusion - A false visual perception experienced by a pilot which is a result of his misinterpretation of a real visual image or is a fabrication of a visual image. This becomes a problem when a pilot is misled by the visual illusion or distracted to the point that he fails to refocus his attention on the flying tasks in time to recognize and respond to cues of impending disaster.

With the exception of overconfidence and excessive motivation to succeed, these factors are typically situational factors. In an aircraft they become critical because the pilot's time to respond to situational demands is brief; therefore, the time-compressed information-processing nature of the pilot task is what makes these situational factors problematic.

Studying time-compressed information processing may lead to ways to identify a pilot's maximum information-processing capability to reduce the information-processing demands of the more difficult piloting tasks, and/or to increase the pilot's ability to process information. Each of these findings could help reduce pilot-factor mishaps.

Given the potential impact of the time-compressed information-processing factor on the mishap process, aviation technologies regarding this factor will be identified, as with the other eight pilot factors. Time-compressed information processing is defined as follows:

- TCIP--Immediate assimilation of information received so that response can be made within appropriate time limits. This becomes a problem when the time needed to perform some critical task approaches or exceeds the time available because of other mission constraints.

Identification of Aviation Technologies

Various aviation technologies related to pilot factors in aircraft mishaps were identified in a systematic literature review. As for Section II, the articles reviewed for this section were obtained from a thorough search of the overall literature on aviation safety. Appendix A describes the search strategy and contains annotated references.

A standardized review form (Appendix B, Exhibit B-2) provided an easily accessible, systematically organized, and thorough abstract for each study.

Articles chosen for review, based on their significance to pilot factors related to mishaps, are outlined in Figure 3. The figure cross-references the articles to the particular pilot factors which they investigated. For instance, Article 1 (Alnutt, 3), "Investigation of Pattern Recognition of Aircraft Attitude Indicator Displays," utilizes the Fourier Transformation Model (FTM) to evaluate and classify attitude-indicator displays. Spatial disorientation, vertigo, and visual illusion can be studied by using the FTM for pattern-recognition problems. Results of this experiment show that fixed and moving horizon displays are mapped into opposite halves of the linear decision space. This was the basis for predicting that human operators may commit errors of reversal when using the moving horizon display.

For this study, the technologies have been grouped into two phases of application--diagnostic and remedial. Diagnostic measures, used to identify and define specific pilot factors related to aviation mishaps, are designed to analyze the individual's performance and provide information on the causes of difficulty. Remedial measures are applied to the identified problem in an attempt to reduce its severity. In this report, specific instruments or procedures within diagnostic and remedial technologies will be called techniques.

PILOT FACTORS RELEVANT LITERATURE	APPREHENSION	CHANNELIZED ATTENTION	DISORIENTATION	DISTRACTION	EXCESSIVE MOTIVATION TO SUCCEED	OVER CONFIDENCE	STRESS	TIME COMPRESSED INFORMATION PROCESSING	VISUAL ILLUSION	VERTIGO
1 INVESTIGATION OF PATTERN RECOGNITION OF AIRCRAFT ATTITUDE INDICATOR DISPLAYS			FIXED HORIZON DISPLAYS (FTM)						FIXED HORIZON DISPLAYS (FTM)	FIXED HORIZON DISPLAYS (FTM)
2 TRANSITION OF EXPERIENCED PILOTS TO A FREQUENCY SEPARATE AIRCRAFT ATTITUDE DISPLAY			FREQUENCY SEPARATED & MOVING HORIZON DISPLAYS							FREQUENCY SEPARATED & MOVING HORIZON DISPLAYS
3 AN AIRPLANE PERFORMANCE CONTROL SYSTEM (PCS) A FLIGHT EXPERIMENT		PCS VS CONVENTIONAL CONTROL						PCS VS CONVENTIONAL CONTROL		
4 PERIPHERAL VISION AND TRACKING PERFORMANCE UNDER STRESS							SAT 1 SIMULATOR	MODIFIED STERNBERG MEMORY PROBE		
5 EFFECTIVE APPROACHES TO DISORIENTATION FAMILIARIZATION FOR AVIATION PERSONNEL			ROTATING CHAIR							ROTATING CHAIR
6 DISORIENTATION TRAINING IN FAA-CERTIFIED FLIGHT AND GROUND SCHOOLS A SUMMARY			EVALUATION OF DISORIENTATION TRAINING			EVALUATION OF DISORIENTATION TRAINING				EVALUATION OF AMOUNT OF TRAINING
7 RESIDUAL ATTENTION AS A PREDICTOR OF PILOT PERFORMANCE		MRT INDEX								
8 VISUAL SCANNING: COMPOSITIONS BETWEEN STUDENT AND INSTRUCTOR PILOTS-EXPERIMENT NO. 1		VISUAL STIMULUS RESPONSE								
9 VISUAL SCANNING: COMPOSITIONS BETWEEN STUDENT AND INSTRUCTOR PILOTS-EXPERIMENT NO. 2		RANDOM MATRIX POSITIONING								
10 HUMAN FACTOR CONDITIONS IN PILOT WARNING INSTRUMENT SYSTEM		PILOT WARNING INSTRUMENT						PILOT WARNING INSTRUMENT		
11 TIME ESTIMATION AS A TECHNIQUE TO MEASURE WORKLOAD				TIME ESTIMATION PARADIGM				TIME ESTIMATION PARADIGM		
12 PILOT PERFORMANCE AND HEART RATE DURING IN-FLIGHT USE OF A COMPACT INSTRUMENT DISPLAY	MEASURE OF HEART RATE	INSTRUMENT DISPLAY						MEASURE OF HEART RATE		
13 GENERAL AVIATION PILOT STALL AWARENESS TRAINING STUDY			STALL/SPIN TRAINING							STALL/SPIN TRAINING
14 HOW MUCH SHOULD YOU PAY FOR THAT DOX?		VALUE OF TRAINING	VALUE OF TRAINING							VALUE OF TRAINING
15 RATIONALE FOR IMPROVING PROTECTION AGAINST MIDAIR COLLISIONS		USE OF MIDAIR COLLISION AVOIDANCE DEVICES								
16 AIR COMBAT MANEUVERING PERFORMANCE MANEUVERING					LEVEL OF EXPERIENCE QUESTIONNAIRE	LEVEL OF EXPERIENCE QUESTIONNAIRE				
17 SIMILARITIES & DIFFERENCES AMONG SUPERIOR, MARGINAL AND ELIMINATED UNSUBORDINATE PILOT TRAINING						ADEQUACY OF TRAINING PROGRAM				
18 A PSYCHOLOGICAL APPROACH TO AIRCRAFT SAFETY					PSYCHOLOGICAL PROFILE	PSYCHOLOGICAL PROFILE	PSYCHOLOGICAL PROFILE			
19 MODELING THE EFFECTS OF ENVIRONMENTAL FACTORS ON HUMAN CONTROL AND INFORMATION PROCESSING			LABORATORY TRACKING TASKS (LTT)		LABORATORY TRACKING TASKS (LTT)		LABORATORY TRACKING TASKS (LTT)			LABORATORY TRACKING TASKS (LTT)

Figure 3. Matrix of human factors/aviation technologies--Literature review.

PILOT FACTORS RELEVANT LITERATURE	APPREHENSION	CHANNELIZED ATTENTION	DISORIENTATION	DISTRACTION	EXCESSIVE MOTIVATION TO SUCCEED	OVER CONFIDENCE	STRESS	TIME COMPRESSED INFORMATION PROCESSING	VISUAL ILLUSION	VERTIGO
20 TRAINING RESEARCH PROGRAM PLANS ADVANCED SIMULATION IN UNDERGROUND PILOT TRAINING			ASUP1 SIMULATORS 1-40 1-46					ASUP1 SIMULATORS 1-40 1-46		ASUP1 SIMULATORS 1-40 1-46
21 IDENTIFYING AND QUANTIFYING THE CRITICALITY OF HUMAN FACTOR DEFICIENCIES IN NAVAL AIRCRAFT COCKPIT	QUESTIONNAIRE	QUESTIONNAIRE	QUESTIONNAIRE				QUESTIONNAIRE			QUESTIONNAIRE SIMULATORS
22 EVALUATION OF A PILOT WORKLOAD METRIC FOR SIMULATED VLOL LANDING TASKS			NASA-LANGLEY VISUAL MOTION SIMULATOR (VMS)				PHYSIOLOGICAL (FM) RECORDING TECHNIQUES	WORKLOAD OPINION QUESTIONNAIRE		
23 VALIDATION OF AN IN-FLIGHT PERFORMANCE MEASUREMENT METHODOLOGY - 4 GROUND ATTACK TRAINING EVALUATION								STAGE BY STAGE RATING OF PILOT PERFORMANCE		
24 MIDAIR COLLISION PREVENTION OF HIGH LOW ALTITUDE TRAINING RESULTS		ADVANCED WARNING DEVICE		STROBE						
25 EVALUATION OF SIMULATORS ROLE IN TRAINING AIRBORNE ASW OPERATIONS IN BEHAVIORAL ASPECT OF AIRCRAFT ACCIDENT PATTERNS		VARIETY OF SIMULATORS								
26 EVALUATING THE SENSITIVITY OF VARIOUS MEASURES OF OPERATOR WORKLOAD USING RANDOM DUTIES IN SECONDARY TASKS		MEASURES RESPONSE TIME						MEASURES DEPENDENT VARIABLES		
27 APPLICATION OF A PERFORMANCE MODEL TO ASSESS AVIATOR CRITICAL INCIDENT						TAXONOMIC MODEL	TAXONOMIC MODEL	TAXONOMIC MODEL		
28 VOICE STRESS ANALYSIS AS A MEASURE OF OPERATOR WORKLOAD	RESPONSE TESTER & PSYCHOLOGICAL STRESS EVALUATOR						RESPONSE TESTER & PSYCHOLOGICAL STRESS EVALUATOR			
29 PILOT PERFORMANCE DURING FLIGHT SIMULATION WITH PERIPHERALLY PRESENTED VISUAL SIGNALS				STEADY PERIPHERAL INSTRUMENT LIGHTING VS STROBE			GAT 1 SIMULATOR	GAT 1 SIMULATOR		
30 ESTIMATION OF UGARD SAFETY BENEFITS		UPGRADED THIRD GENERATION ATC SYSTEM								
31 CONTINUATION VS RECURRENT PILOT TRAINING								INCREASE FLIGHT TIME		
32 ENDOCRINE METABOLIC EFFECTS IN SHORT DURATION HIGH WORKLOAD MISSION? FEASIBILITY STUDY	QUESTIONNAIRE						QUESTIONNAIRE URINE SAMPLES	QUESTIONNAIRE		
33 MISSION CREW FATIGUE DURING REPEATED OPERATIONS	FATIGUE DATA SLEEP LOGS						FATIGUE DATA SLEEP LOGS			
34 VISUAL COLLISION AVOIDANCE IN HIGH SPEED LOW ALTITUDE FIGHTING AND TRAINING OPERATIONS		VISUALLY ESTIMATING ANGLES FOR COLLISION AVOIDANCE								
35 BEHAVIORAL MEASURES OF AIRCREW MENTAL WORKLOAD		SUBJECTIVE WORKLOAD MEASURES					SUBJECTIVE WORKLOAD MEASURES	SUBJECTIVE WORKLOAD MEASURES		
36 PROPOSED MILITARY CHARACTERISTICS OF COLLISION WARNING DEVICE IN USE		ELECTRONIC DETECTION DEVICE								
37 THE EFFECTS OF CERTAIN SYMBOL ORDER ON TARGET ACQUISITION AND WORK LOAD			SIMULATED TARGET RUNS					SIMULATED TARGET RUNS		

Figure 3 (continued).

Figure 4 is a breakdown of specific techniques now being applied to major pilot factors; it can be used as a ready reference for techniques suited to diagnose and remedy pilot factors in aircraft mishaps. The figure shows three broad diagnostic technologies--questionnaires/interviews, physiological measures, and simulators. Simulators can also be used as remedial techniques applied to training. The following discussion more fully describes these technologies and discusses some specific techniques.

Diagnostic Technologies--Diagnostic technologies provide information regarding a pilot's sociopsychological and physiological baseline state. Present operational ability and skill level can be determined by psychological assessment using measures such as questionnaires and interviews; physiological measures such as fatigue data, sleep logs, heart rate, and urine samples; and simulators with tests designed to measure performance during actual working tasks.

1. Psychological Assessment. One survey technique that can be used to assess pilot performance is a questionnaire. Because of the relative ease and speed with which it can be administered, the questionnaire has definite advantages in survey research; it saves both time and expense. This technique can be aimed at obtaining factual data as well as opinions, impressions, or estimates. The written questionnaire may be regarded as a substitute for the personal interview. The disadvantages of the questionnaire lie in the uncertainty of obtaining replies and in the difficulty of extracting reasons behind responses; there is no opportunity for an interviewer to probe the respondents and clarify opinions, perceptions, and misconceptions.

In a survey, the most common and effective means of obtaining the necessary data is the personal interview. It allows the interviewer to gain in-depth information from the interviewee. Detailed plans must be made to minimize bias. Use of structured interview techniques is expensive and hampered by time constraints.

Paper and pencil tests and/or interviews have been used to determine psychological profile, information-processing capacity, aircraft preference, and assessment of aircraft-handling capability. Although Krause (30) presented no data as to the actual effectiveness of the psychological profiles, the information is useful in applying psychological principles to aviation safety. Emphasis is on the salient psychological attributes of the pilot. These tests provide necessary information regarding a behavioral framework to motivate the pilot toward flight safety.

The SAM stress battery, for example, is administered to evaluate anticipatory stress and mild flight stress (Smith and Matheny, 52). This stress battery appears to be a useful addition to flight instrumentation in assessing pilot workload as it applies to designing more effective cockpit displays. When administered 1 hour prior to each flight and 30 minutes after each flight, the SAM stress battery is valuable in assessing subjective pilot fatigue by questionnaire methods. Technical understanding and adequacy of training programs are measured through questionnaires and observational techniques (King and Eddowes, 27; Matheny, 32; Mowbray, 33). Posttraining interviews identify pilots' problems related to safety, training methodology, skill

IDENTIFIED TECHNOLOGIES PILOT FACTORS	DIAGNOSTIC TECHNOLOGIES			REMEDIAL TECHNOLOGIES	
	QUESTIONNAIRES/ INTERVIEWS	PHYSIOLOGICAL MEASURES	SIMULATORS	TRAINING	SIMULATORS
APPREHENSION	<ul style="list-style-type: none"> • NAVAL AVIATOR QUESTIONNAIRE • SAM STRESS BATTERY • RESPONSE ANALYSIS TESTER • VOICE STRESS EVALUATION 	<ul style="list-style-type: none"> • MEASURE HEART RATE • FATIGUE DATA • SLEEP LOGS 			
CHANNELIZED ATTENTION	<ul style="list-style-type: none"> • SUBJECTIVE OPINION STUDIES • PCS/CONVENTIONAL CONTROL QUESTIONNAIRE • INSTRUMENT PANEL DESIGN INTERVIEW • NAVAL AVIATOR QUESTIONNAIRE 		<ul style="list-style-type: none"> • PCS/CONVENTIONAL CONTROL FLIGHT TEST • MRT INDEX • VISUAL SCANNING MATRIX • RANDOM MATRIX POSITIONING • FIDELITY & MOTION STUDIES • LED DISPLAY FOR RESPONSE TIME ANALYSIS • COLLISION WARNING DEVICE 	<ul style="list-style-type: none"> • FIDELITY & MOTION STUDIES • ACAS/BCAS/IPC • REDUCE TRAINING ROUTES • IMPROVED USE OF 3rd GENERATION ATC • VISUALLY ESTIMATING ANGLE FOR COLLISION AVOIDANCE 	<ul style="list-style-type: none"> • VISUAL SCANNING MATRIX • RANDOM MATRIX POSITIONING • DFT/WST
DISORIENTATION	<ul style="list-style-type: none"> • QUESTIONNAIRE ON ADEQUACY OF TRAINING • NAVAL AVIATOR QUESTIONNAIRE 		<ul style="list-style-type: none"> • FOURIER TRANSFORMATION MODEL • LINK GAT 2 ATTITUDE DISPLAY • VERTIGON • MODIFIED LINK TRAINER • LABORATORY TRACKING TASKS (OPTIMAL CONTROL MODEL) • ADAPT DEVICE • GIMBAL ORDER TESTING • RASA/LANGLEY VISUAL MOTION SIMULATOR (VMS) 	<ul style="list-style-type: none"> • STALL/SPIN INSTRUCTION 	<ul style="list-style-type: none"> • FIDELITY/MOTION SYSTEM • ADAPT DEVICE
DISTRACTION			<ul style="list-style-type: none"> • STEADY LIGHT VS STROBE LIGHT INSTRUMENT 	<ul style="list-style-type: none"> • TIME ESTIMATION PARADIGM 	<ul style="list-style-type: none"> • STROBE
EXCESSIVE MOTIVATION TO SUCCEED	<ul style="list-style-type: none"> • UPT ATTRITION STUDY QUESTIONNAIRE • PSYCHOLOGICAL TEST BATTERY • LEVEL OF EXPERIENCE QUESTIONNAIRE 				
OVERCONFIDENCE	<ul style="list-style-type: none"> • QUESTIONNAIRE ON ADEQUACY OF TRAINING • PSYCHOLOGICAL TEST BATTERY • LEVEL OF EXPERIENCE QUESTIONNAIRE • TAXONOMIC MODEL 				
STRESS	<ul style="list-style-type: none"> • PSYCHOLOGICAL TEST BATTERY • NAVAL AVIATOR QUESTIONNAIRE • SAM STRESS BATTERY • WORKLOAD MEASURES • VOICE STRESS EVALUATION • TAXONOMIC MODEL 	<ul style="list-style-type: none"> • MEASURE HEART RATE • URINE SAMPLES • FATIGUE DATA • SLEEP LOGS • PHYSIOLOGICAL (FM) RECORDING TECHNIQUES 	<ul style="list-style-type: none"> • LABORATORY TRACKING TASKS (OPTIMAL CONTROL MODEL) • CAT 1 		
TIME COMPRESSED INFORMATION PROCESSING	<ul style="list-style-type: none"> • PCS/CONVENTIONAL CONTROL QUESTIONNAIRE • WORKLOAD OPINION QUESTIONNAIRE • TAXONOMIC MODEL 		<ul style="list-style-type: none"> • PCS/CONVENTIONAL CONTROL FLIGHT TEST • STAGE BY STAGE RATING OF PILOT PERFORMANCE • CAT 1 	<ul style="list-style-type: none"> • TIME ESTIMATION PARADIGM 	
VERTIGO	<ul style="list-style-type: none"> • QUESTIONNAIRE ON ADEQUACY OF TRAINING • NAVAL AVIATOR QUESTIONNAIRE 		<ul style="list-style-type: none"> • FTM • LINK GAT 2 ATTITUDE DISPLAY • ROTATING CHAIR • VERTIGON • MODIFIED LINK TRAINER • FIDELITY/MOTION SYSTEM • LABORATORY TRACKING TASKS • ADAPT DEVICE 	<ul style="list-style-type: none"> • STALL/SPIN INSTRUCTION 	<ul style="list-style-type: none"> • FIDELITY/MOTION SYSTEM • ADAPT DEVICE
VISUAL ILLUSION			<ul style="list-style-type: none"> • FTM 		

Figure 4. Matrix of human factors/identified technologies.

level, and instructor adequacy. Information on human engineering and safety deficiencies in cockpit design can also be gathered to provide a valuable data base for relative incidence of human-factor problems.

2. Physiological Measures. These measures are concerned with the relations between behavior, anatomy, and physiology. The physiologic data are used to detect the relationship between some physiological condition and changes in behavior. Respiratory, auditory, visual, and nervous systems all respond to changes in physical environment. Performance degradation is related to fluctuations in these physiological systems. Postflight urine samples and in-flight monitoring of pilot heart rates are used to measure stress and apprehension (Mowbray, 33; Hasbrook et al., 22). Both assess flight stress and fatigue as a function of workload. Recent studies in the area of voice stress analysis have used voice-signal instruments to measure operator workload (Stodola, 53); stress ratings in speech were correlated with performance scores. Information on subjective level of fatigue and loss of sleep are collected before and during the airborne missions (Storm and Hapenny, 55). These data provide the pilot and groundcrew with baseline information to refine procedures and analytical techniques when preparing for demonstration/evaluation of new and modernized equipment. Information obtained from these various physiological measures helps in understanding causal factors such as fatigue and overt hypertension due to time-compressed information processing, apprehension, and stress.

3. Simulators. The value of aircraft simulators as diagnostic tools is their ability to reduce cost, improve efficiency, and heighten the effectiveness of pilot performance. Transfer effects to actual aircraft flight are normally positive. Simulator testing allows close maintenance and assessment of pilot proficiency.

Using simulators as a diagnostic tool to measure pilot performance includes such applications as establishing a median response time (MRT) index. This test measures residual attention as a function of a primary task (one-dimensional, compensatory tracking) and a secondary task (choice reaction). It also measures the time necessary to react to a secondary stimulus (Collins, 10).

Simulators are the primary vehicle for direct testing of pilot performance. They may be used to investigate gimballed order systems (roll-pitch, yaw-pitch, and pitch-yaw) as they affect pilot disorientation (Williges and Wierwillie, 57). Gimballed order negatively affects target detection, recognition, and identification performance; it also increases operator workload during target detection, recognition, and identification responses. In both cases the roll-pitch has been the worst.

Simulators must not, however, be viewed as the universal panacea to all flight training problems. No matter how realistic the simulation is, it is still only a simulation. The actuality of catastrophic failure resulting in loss of life simply does not exist. Some aviators believe that without this real-world factor, involvement in simulator training will not be total and therefore the training may not be as effective as training in flight.

A host of studies have been conducted to lend support to the transfer-of-training hypothesis. The general results are supportive of transfer, with effectiveness varying directly with fidelity. No matter how much research support there is, however, training effectiveness of a simulator will not be enhanced if the pilot does not accept the result of the research. Future work in the area of simulation effectiveness should emphasize the stimulation of positive and negative results of pilot behavior. For example, a schedule of reinforcement could be constructed to reward the pilot for good performance and penalize him for poor performance in the simulator. Currently, all reinforcement for simulator training is internal and based on pride of accomplishment. Perhaps simulator competition among pilots, based on this inherent pride coupled with meaningful schedule of rewards and punishment, may offset the distrust of simulator effectiveness present in a small segment of the pilot population.

Pilot-warning instruments (PWI) have been used to test channelized attention and time-compressed information processing (Graham, 19). The PWI alerts the pilot to the presence of potentially threatening aircraft and thereby increases his probability of detecting threat environments. The pilot's behavior, as it relates to the simulated stimuli, requires further study. The relationships between the nature of the alarm system and pilot performance are some human-factor considerations in PWI design.

Recognition of disorientation and vertigo can be tested by using a motor-driven rotating chair to simulate aircraft motion. The pilot is asked to indicate turning rate and direction, as well as to report his sensations (Collins, 11). The pilot becomes familiar with the sensations associated with disorientation. Other pilots observe the process and subsequent behavior and report their reactions.

Diagnostic technologies are designed to measure a pilot's overall performance under varying conditions. This testing provides data that may be used to modify existing training programs, functionally redesign equipment to eliminate and/or reduce pilot error, and determine psychological and physiological states. The literature review (as illustrated in Fig. 4) indicated that many pilot factors do not have associated diagnostic technologies readily available.

Remedial technologies--Technologies that may actually provide solutions to human-factor problems in aircraft mishaps are categorized as remedial technologies. These include training and simulators. The purpose of identifying such technologies is to enhance pilot awareness and performance through training and use of simulators. Both have immediate practical application to the pilot's job and augment his ability to perform in a safe manner.

1. Training. To be at its best, most performance must be enhanced by training--providing the pilot with the knowledge, skill, or attitude needed to perform at an expected standard. Remedial training improves individual performance by enhancing an operator's ability to use tools, methods, and processes in a systematic manner.

Research indicates that undergraduate and preflight training problems are generally related to student attitude toward the overall training program. Skill acquisition is directly related to the orientation program, level

of confidence, and instructor/student pilot relationships (King and Eddowes, 27). Post-flight-school training, on the other hand, is more specific in nature and results in upgraded response times. Two levels of specificity provide the pilot with training: first at the basic needs level, and later, with more experienced pilots, at the specific skill level.

Pilots' ground training in stalls and spins, even the awareness of these factors, has a positive influence toward reducing inadvertent stalls and spins. One study (Hoffman and Hollister, 23) identified weaknesses of present training methods used in spins and stalls; actual in-flight training was deemed most helpful in dealing with this phenomenon.

2. Simulators. Simulators are used extensively to train for responses to situations likely to occur during actual mission. Most studies indicate that learning takes place and transfers positively to the operational environment. Effectiveness of simulator training depends mostly on the training procedures (Hopkins, 24). Other factors alleged to influence the effectiveness of simulators vary in their demonstrated importance, however, and the transferability of simulator motion training to actual flight training has been questioned. Simulators do cost less to acquire, operate, and maintain than their counterpart aircraft, and are effective training technologies.

Simulation of flight exercises is easy to control in terms of cost and error rate. For example, the Operational Flight Trainer (OFT) is used to train student pilots, co-pilots, and flight engineers on both nominal and emergency aircraft operating procedures (Robins and Ryan, 40). Computer equipment in the Weapons Systems Trainer (utilized in conjunction with the OFT) records the effects of operator performance at varying crew stations. These are monitored by the instructor who can "freeze" the simulated conditions at any time during the conduct of training. This allows the instructor to stop the training, discuss and correct erroneous performance, and either reset the same situation or continue with the simulation exercise.

Discussion

This section deals primarily with the application of specific technologies described in the research study. Each identified pilot factor is discussed with regard to 1) the direct application of technologies to the causal factors in aircraft accidents, and 2) selected technologies that are available for immediate application. Figure 4 indicated the most plausible techniques to be applied to the identified pilot factors. These techniques will be discussed here only as representative samples of diagnostic and remedial technologies. In Section V, as they are developed into specific programs, the techniques will be applied to the major pilot factors more directly.

• Apprehension--The level of apprehension experienced by pilots is measured by surveys (questionnaires/interviews) and physiological measures. The Naval Aviator questionnaire and the SAM stress battery provide information as to the pilot's psychophysiological state (Mowlbray, 3). To determine physiological condition, the pilot's heartrate is measured while in flight or in a laboratory-simulated environment. Another assessment technique, the

Psychological Stress Evaluator (PSE), is used to code voice signals that can be subjectively scored to measure stress or apprehension-level patterns in the pilot's speech (Schiflett, 46). These patterns are also translated into electronic equivalents and automated on a Varian 73 computer for voice pattern recognition analysis. This analysis can be applied to apprehension and stress in vocal communication systems that require operator workload assessments.

Fatigue data and sleep logs provide additional data to indicate expected level of stress and apprehension (Storm et al., 54). These techniques provide the investigator with subjective and objective data on the psychophysiological state of the pilot. Attempts can then be made to determine and reduce the causes of high levels of stress, fatigue, and apprehension. In this way, the anxiety level involved in task completion can be minimized.

The literature review did not identify any technologies designed specifically to reduce the effects of apprehension. Diagnosing the problem is fundamental, but no apparent technology exists to eliminate it as a factor in aircraft mishaps.

• Channelized Attention--Factors that commonly increase the degree to which a person attends to stimuli are--

- (1) motivational characteristics of the individual,
- (2) movement of stimuli, and
- (3) contrast of the stimuli with overall (background) conditions.

A variety of techniques have been used to study the causes of channelized attention. These include comparison of the Performance Control System (PCS) and the conventional flight control with subsequent questionnaire assessment (Bergman, 6). With the PCS, flight error scores were reliably lower than with the conventional aircraft controls. Pilots showed a moderate preference for the PCS. With further development, the PCS may become a reliable method of remedying channelized attention.

The instrument panel design interview and the Naval Aviator questionnaire (Hasbrook, 22; Mowlbray, 33) have been used as survey techniques; both request information as to the pilot's instrument-scanning capability. The idea of a simplified instrument panel design was favorably received by the pilots, as indicated in an instrument-panel-design interview. Human-factor deficiency data in cockpit design can be identified with the Naval Aviator questionnaire. Eliminating confusion in the instrument panel design will reduce the possibility of pilots experiencing channelized attention due to unfamiliarity and confusion with cockpit displays.

In addition, a variety of simulated environments can create a range of scenarios designed to induce channelized attention. In this way, the factors contributing to channelized attention can be isolated and removed. The median response time (MRT) index measures residual attention by testing a primary task (one-dimensional, compensatory tracking) and a secondary task (choice reaction) (Jenos, 14). An MRT measures time to react to the secondary

task. Fidelity and motion studies and response-time analyses all provide additional simulated situations to diagnose or remedy channelized attention as a factor in pilot errors (Collins, 11; Levison et al., 31; North and Graffunder, 35).

Remedial techniques with regard to training include various collision-avoidance methods which familiarize the pilot with channelized attention data (Israel et al., 25). These collision-avoidance devices provide the pilot with information to augment current ground systems. By automatically monitoring and checking for possible collisions, the channelized-attention factor in midair collisions is reduced.

Certain simulators have proven effective in familiarizing the pilot with channelized-attention dangers. The Operational Flight Trainer, which contains the Weapons Systems Trainer, separates skills required for aircraft operation from submarine detection, tracking, and destruction (Robins and Ryan, 40). This particular simulated flight environment allows the instructor the flexibility to interrupt a situation long enough to discuss and correct erroneous behavior.

All of these techniques help the pilot recognize and be familiar with the effect of channelized attention. Recognizing specific signals or signs will ultimately decrease the occurrence of channelized attention.

• Disorientation--Awareness of and correct response to disorientation requires proper training and recognition. Techniques to be applied to spatial disorientation in pilots include questionnaires discussing the phenomenon, such as the Naval Aviators questionnaire (33). This questionnaire is open-ended in four major categories: 1) controls and primary tactile functions; 2) displays and primary visual functions; 3) psychological factors; and 4) miscellaneous factors. Though used primarily to gather human-factor data on cockpit design, the questionnaire deals specifically with operator inefficiency as a function of safety concepts. Motion-related displays as they aid in visual functions are tested for adequacy in this questionnaire.

Questionnaires designed to evaluate the adequacy of pilot training in disorientation are also available (Collins, 10). Significantly, one-third of the respondents in Collins' study found their disorientation training inadequate, usually due to a lack of appropriate materials, aids, and information. This questionnaire could be utilized as a diagnostic or remedial measure.

Simulated laboratory exercises, such as with the Link GAT-2 attitude display and the Vertigon, are available to test a pilot's awareness of disorientation (Bateman, 4; Beringer et al., 7; Collins, 10). These simulations deal with the issue of perceptions and classification of attitude, roll rate, and symbol response times. The Link GAT-2 attitude display helps detect deflections in attitude and provides control-compatible prediction indications of flight-attitude changes. Conventional moving horizon displays are retained during the presentation. The motor-driven rotating chair, Vertigon, and modified Link Trainer all familiarize the pilot with the sensation of disorientation and fidelity/motion information. Their data provide the pilot with personal processing capabilities when confronted with disorientation.

- Distraction--Very little has been reported in the area of pilot distraction. No technologies to prevent distraction were identified from the literature review. Obvious deficiencies exist in diagnostic technologies to deal with response to and recognition of stimuli outside task-related responsibilities. Further techniques need to be identified to eliminate this problem.

Studies were identified that dealt with the use of steady lights as opposed to strobe lights on instrument panels (Read, 38). The objective was to test the alternatives and identify the most nonobstructive instrument display. Visual performance seemed to be better when peripheral strobe lights were used (Schwank, 47). It was determined, however, that steady light indicators used for heading deviations should not be detrimental to the pilot's performance. When light indicators were not functioning properly, however, the pilot's ability to respond was distracted away from other aircraft instruments.

Distraction can also be used in a positive sense. Strobes mounted on aircraft were proposed as a means of positively distracting pilot's attention from regular duties to the possibility of a midair collision (Read, 38). No real technology is available to measure or systematically study pilot distraction. Time estimation, a technique for measuring workload, has been used with limited success. This technique requires subjects to estimate time lapses while performing a series of tasks. Investigators then observe the effects of these tasks on subjects' perceptions of time. More definition is needed, however, of the types of tasks that are most appropriate for this method of investigation.

- Excessive Motivation To Succeed--Personality variables that impact on pilot performance can be measured by the UPT Attrition Study Questionnaire and psychological test batteries (Levison et al., 31; Krause, 30). The purpose of such examinations is to uncover the salient psychological attributes of a pilot and thereby provide a behavioral framework from which to motivate that pilot to a safe level.

A minimal amount of study has been completed on excessive motivation to succeed. Air combat mission experience, as it relates to performance assessment during air-to-air combat, has provided many unique measurement problems (Israel et al., 25). A list of measures was developed to discriminate between high- and low-skilled pilots. The questionnaire and interview technique was useful in analyzing performance, though designed to determine skill-level data. This system, however, is not ready for implementation or operational use.

- Overconfidence--Overconfidence is defined as unrealistic belief in aircraft ability or in one's own ability as a pilot, and manifests itself in unnecessary risk taking. To minimize this behavior, a psychological test battery can be administered along with a questionnaire to determine the pilot's evaluation of his training (Collins, 10; Krause, 30). These psychological profiles provide a theoretical framework that should motivate pilots to act safely, a theory derived from positive and negative reinforcement and punishment. Attitudes toward the amount of training received may also indicate a pilot's propensity to be overconfident about himself and the aircraft. The

test battery indicates the pilot's perceptions of personal ability and the adequacy of the training received, but further study is needed to identify diagnostic and remedial techniques.

- Stress--Pilot stress can be measured in a variety of ways. As mentioned earlier, established survey instruments such as the psychological test battery, Naval Aviation questionnaire, and SAM stress battery are helpful (Krause, 30; Mowlbray, 33; Smith and Matheny, 52). These instruments provide data on the level of information processing that a pilot can handle. Measuring the perceived workload demands by psychological questioning and interviewing helps determine if the pilot is being tasked beyond his capability to complete a mission successfully. Physiological measures such as heart rate, urine samples, and fatigue data may also be used (Smith and Matheny, 52; Savage et al., 45). These factors are helpful if used in conjunction with other measurement techniques. Reliable data may also be identified by voice stress analysis (Schiflett, 46). Though not proven conclusively, correlations apparently exist between the level of voice stress and performance. The results might also be applied to measure stress in vocal communication systems that require operator-workload assessment.

Simulated laboratory tracking tasks are also used to measure stress (Levison et al., 31) and can be used to desensitize the pilot to external stress and lower the level of excitability. For example, familiarity with roll-axis and steady-state tracking situations may be helpful. The objective is to make the pilot aware of unfavorable attitudes so that the responses in stressful environmental situations do not become excessive.

No techniques to remedy stress were identified in the literature. Most studies deal with determining if stress exists and in what specific ways it is manifested in pilot behavior. More emphasis needs to be placed on eliminating the problem psychologically and physiologically. The design of tasks and equipment should be sensitive to these problems.

- Vertigo--Studies in disorientation and vertigo are similar, and techniques to reduce the effects are essentially the same. Techniques described under "Disorientation" are used to familiarize the pilot with the sensation.

Although most studies deal with disorientation and vertigo as the same phenomenon, BDM defines these two as separate, though related, factors that affect aircraft mishaps. Disorientation is the loss of one's place in relation to the ground, while vertigo is the sensation of rotating. Both problems can be manifested in the same manner. In treating the problem, fidelity in motion and stall/spin instruction familiarize the pilot with the sensation, and help discriminate between the two causes. Also, using simulators to reinforce pilot reliance on attitude displays may prove effective in eliminating vertigo as a factor in aircraft mishaps.

- Visual Illusion--Misinterpreting a real visual image or fabricating an unreal image causes a pilot to become distracted. These false perceptions result in loss of focus on the task at hand and impede proper response. Although proper response to visual cues can be conditioned, no study identified techniques available to eliminate response to visual illusions.

Summary

The purpose of this section was to describe and identify aviation technologies that have a potential for reducing or eliminating aircraft mishaps due to major pilot factors.

The four general technologies identified for use to study and remedy pilot-factor mishaps are 1) questionnaires and interviews, 2) physiological measures, 3) simulators, and 4) training.

Specific instruments and procedures within these broad technology areas were examined, and their applicability to specific pilot factors.

No one technology is best for application to any given pilot factor. To successfully eliminate any pilot factor, multiple technologies must be applied in a programmatic fashion.

V. U.S. AIR FORCE PROGRAMS DESIGNED TO APPLY HUMAN-FACTOR TECHNOLOGIES
TO ACCIDENT INVESTIGATION AND PREVENTION

The overall purpose of this section is to describe comprehensive programs of research in the domain of the behavioral sciences which will aid in investigating and preventing aircraft mishaps related to pilot factors. Our goal has been to

- (1) describe an integrated programmatic approach to the prevention of pilot-factor mishaps,
- (2) describe/define a general research strategy that will guide the application of human-factor technologies to prevent mishaps related to pilot factors,
- (3) delineate several specific research projects aimed at preventing aircraft mishaps by using techniques from high-payoff areas of investigation, and
- (4) propose the "best case" research project within the context of the integrated programmatic approach.

Integrated Approach to the Investigation/Prevention
of Pilot-Factor Mishaps

As indicated by literature reviews in the areas of mishap investigation and human-factor technologies, the field of aviation safety research is in a state of disarray. The research is characterized by fragmented attempts to solve various aspects of ill-defined phenomena that may or may not be traceable as causal elements in aircraft mishaps. Both our experience and serendipitous findings in other areas of transportation safety research have indicated that this disarray also pertains to ground and sea transportation. This evident confusion is not solely the fault of the researchers. In fact, transportation safety problems are difficult to solve mainly because they are manifested in "rare events." For example, there are approximately 50,000 highway traffic deaths each year, but this seemingly horrendous figure (approximately equal to all U.S. Viet Nam combat deaths) translates to 3.9 fatalities per 100,000,000 vehicle miles (Accident Facts, 1979*). Since the average trip length is approximately 9 miles (Federal Highway Accidents, 1972*), one's probability of being involved in a fatal accident on the highway is .00000034. One major problem when dealing with extremely rare events is that they are not amenable to the usual statistical manipulation; i.e., they are not normally distributed. This causes great difficulty in attempting to calculate correlations between mishap occurrence and assumed causal factors. To illustrate this point, in the entire history of correlational studies in traffic safety, very few psychological variables in the operator have been proven to be significantly correlated with the occurrence of an accident.

*Personal communication. James McKnight, National Public Service Research Institute, Dec 1979.

We also have the problem of public acquiescence. Based on the unfounded assumption that "it can't happen to me," the American public has tacitly accepted this "human sacrifice" as the cost of private auto transportation. In addition, automobile accident investigation procedures vary from state to state and, indeed, from individual to individual.

Military aviation has several inherent advantages that make its mishap problem more amenable to research and development than is automobile safety. First and foremost, investigative and remedial techniques with potential value for reducing aviation mishaps can be implemented. For automobile safety in the civilian community, remedies can only be suggested to the state motor vehicle administration. In addition, the population of Air Force aviators is much more homogeneous than the civilian driving population. This provides an immeasurable advantage in both reliability and validity when developing new investigative techniques and preventive measures. Finally, there is a real desire and commitment within the Air Force to solve the problem of pilot-factor mishaps. Taken together, these advantages provide a positive climate in which to undertake an effective research and development program.

The key to effective reduction of pilot-factor mishaps is an integrated program of research that represents the Air Force commitment to mishap reduction. A program such as this requires three elements: 1) a pilot-factor mishap data collection system to define causes in operational terms, 2) an integrated series of research projects applying remedial technologies to the identified pilot factor, and 3) a computerized data base management system to provide a communication link between the investigative research and the technology application.

The mishap data collection system includes at least two components: a data collection form and a pilot-factor investigator's checklist (job performance aids). Development of the form requires further refinement of the definitions of relevant pilot factors from Section II. The form must then be applied on a trial basis and undergo iterative "fine tuning." The pilot-factor investigator's checklist will require 1) research on error detection and fault-free analysis, 2) specification of Air Force investigation technologies, and 3) research on real-time investigator job analysis.

An integrated series of research projects (the product of this current research effort) are based on standard problem-solution strategy and are aimed at applying human-factor technologies in the areas identified by the mishap data collection system. Establishment of a pilot-factor data base to provide communication between the investigation enhancement program and the technology application research program will require detailed front-end analysis, review of existing and emerging computer hardware, and an extensive system-architecture effort. These three elements, when in full operation, can be viewed as a pilot-factor mishap reduction system illustrated in Figure 5.

When operational, the system would include an investigation enhancement program that would constantly accept data from near-mishaps via a near-miss hot line or some other reporting method. Data regarding situational, behavioral, psychological, and equipment variables would be collected, coded, and stored in the near-mishap data base. The same type of information would be obtained during pilot-factor mishap investigations, using an enhanced data

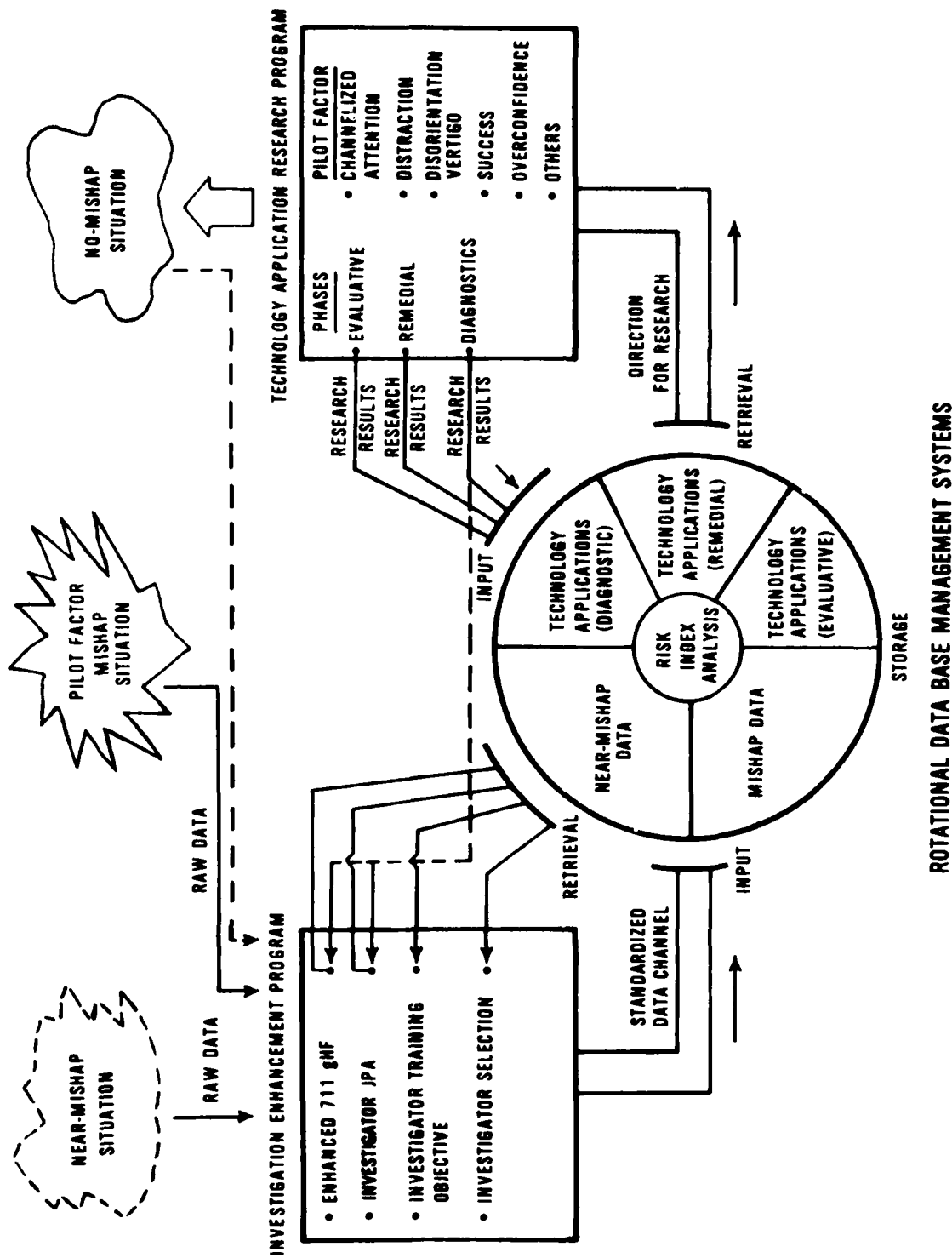


Figure 5. Pilot-factor-mishap reduction system.

collection form and a "programmed" data collection procedure. These techniques would be implemented by specially selected and highly trained pilot-factor investigators. The high reliability and validity of the forms and procedures, together with the well-trained, highly qualified investigators, would provide for standardized data entry.

The data collected from mishaps and near-mishaps would be put into the pilot-factor mishap data base. This data base can be conceived of as rotational in nature. It could be designed with data storage files on the periphery and data analysis function in the center. Once the investigation data are input, stored, and analyzed, their results can be fed back to the investigation enhancement program to refine techniques and be available to the ongoing technology application research.

The purpose of the application research is to provide proven remedial strategies designed to alleviate problems associated with primary pilot factors. Input from the investigation program, which is stored in the data base, could be used to reorder the priorities of selected pilot factors or to add new ones. In addition, extrapolation of trends could be seen as excursions based on the predicted introduction of new tactics, equipment, or pilot-training techniques. Output from the three phases of technology application research would be fed back to the data base for storage and to the investigation program to assist in refining investigation techniques and procedures. Finally, the technology application module would output proven remedial strategies to reduce the contribution of selected pilot factors in specific situations.

General Research Strategy

The focus of the present effort is the Remedial Technology Applications Program. To provide a framework for USAF program development, both a general research model applicable to mishap reduction and a program format to illustrate the model have been devised.

The research strategy to be used consists of a diagnostic, or problem-definition, phase; a remedial, or concept formulation, phase; and an evaluative, or test and evaluation, phase. Based on our review of the literature which included possible causes, investigative techniques, and human-factors/aviation technologies, this is the first time this strategy has been applied to aviation safety research.

Research based on the system development model begins with problem definition. Diagnostics relating to psychological, physiological, and behavioral attributes will be applied to the specific pilot factor under investigation in order to pinpoint the independent variables and dependent measures and to establish hypothetical links between them. Following this activity, concept formulation will begin. This remedial phase describes common variables among human-factor technologies, selects the best remedial approach, and develops a prototype remedial technique applicable to some specific pilot factor. The evaluative phase will provide a test situation based on the dependent measures established earlier within which to determine the potential efficacy of the selected remedial approach. These three phases of research are illustrated in the following program structure.

Phase I: Problem Definition/Diagnostics

- (1) Apply attitudinal measures
 - (2) Apply physiological measures
 - (3) Apply behavioral measures
 - (4) Establish variables, independent and dependent
 - (5) Establish hypothetical constructs or relationships among variables
- } to selected
} samples
} of aviators

The product of Phase I will be the specific pilot factors associated with mishaps. Selection of these factors will be reliable and valid because only those that are pinpointed by all three methods of diagnosis will be selected for future research. Establishing hypothetical relationships among pilot factors and between these factors and potential mishaps will allow prediction with some measure of statistical confidence.

Phase II. Concept Formulation/Remedial Technologies

- (1) Investigate training applications
 - (2) Investigate simulator applications
 - (3) Investigate job performance aids
 - (4) Establish optimal mix based on diagnostics
 - (5) Develop prototype remedial approach for further refinement
- } in regard to
} results of
} diagnostics

Phase II will yield a list of remedial techniques in the areas of training simulation and job performance aids. The Air Force could mix and match techniques from this list in regard to specific pilot factors to construct a prototype remedial program.

Phase III: Evaluation

- (1) Test remedial approach in simulator with selected subject pilot
- (2) Test remedial approach in instrumented range context
- (3) Apply findings to remedial approach in an iterative "fine tuning" effort
- (4) Introduce into real world on a limited basis and monitor performance of selected pilots.

Specific Technology Application Projects

Matrix Overview of Potential Research Options--The major deliverables required from this contractual effort are specific high-payoff research

projects at the 2-, 3-, and 5-manyear levels of effort. The development of these research projects was based on three activities previously described.

In Section II, areas of investigation were identified via analytical literature search and empirical analysis of aircraft mishaps. These areas of research were then rank ordered in regard to cost-related ROI metric in Section III and are defined as follows:

- Channelized Attention - A behavioral phenomenon that occurs when a pilot's full attention is focused on one stimulus to the exclusion of all others. This becomes a problem when the pilot fails to perform tasks or process information of a higher or more immediate priority and thus fails to notice or has no time to respond to cues of impending disaster.

- Disorientation - A loss of one's place-in-space that occurs when a pilot's perception of the aircraft's attitude or motion is incongruent with respect to Earth. This is due to inadequate sensory stimuli, an incorrect interpretation of sensory stimuli due to limitations in sensory receptors, incorrect selection of competing stimuli, or the absence of a general cognitive framework that realistically orients the operator within his environment.

- Vertigo - A form of physiological disorientation that occurs when a pilot senses that he or the external world is rotating. Any form of disorientation becomes a problem when a pilot is not aware of being disoriented and responds according to his incorrect appraisal of the situation, or when the pilot is aware of being disoriented but is unable to, or does not have enough time to, correctly reorient himself while tending to other vital flying tasks.

- Distraction - A behavioral phenomenon that occurs when a pilot's focus of attention on flying tasks is interrupted by a stimulus unrelated to those tasks. This becomes a problem when the pilot fails to refocus attention on flying tasks of a higher or more immediate priority in time to recognize and respond to cues of impending disaster.

- Excessive Motivation To Succeed - A personality characteristic that predisposes a pilot to set unrealistically high standards for himself and to try to perform tasks for which he is knowingly ill-prepared. This becomes a problem when mission success is afforded a higher priority than caution, judgment, or known restrictions.

- Overconfidence - A personality characteristic that a pilot may develop with experience or with positive reinforcement during training. It predisposes the pilot to overestimate personal ability, the ability of others, and/or the ability of the aircraft. It becomes a problem when the pilot attempts to perform tasks that exceed personal or aircraft capabilities.

- Stress - A heightened psychophysiological response state experienced when a pilot perceives that the workload demands of the flight may exceed his capabilities and that the successful completion of the flight is thus threatened. In such a situation, the pilot's adaptive mechanisms become severely taxed. Problems arise when his adaptive mechanisms are taxed to the point that they collapse and the pilot is unable to meet the workload demands of the flight.

Finally, in section IV, aviation technologies related to specific pilot factors were explored, described, and rank ordered in relation to implementation costs.

In this section, five major investigative areas (pilot factors) are identified, also the highest payoff aviation-reduction technologies, both diagnostic and remedial. These "causes" and "solutions" are arranged in a matrix presentation which displays 2-, 3-, and 5-year programs of research. The elements of the required research programs are presented in Figure 6. In this figure, the five major pilot factors and their associated costs are listed, also the phases of problem-solving research with their associated level of effort and period of performance. Within the cells of the matrix are general human factors and aviation technologies that have been or could be applied to specific pilot factors. Under each technology area are specific diagnostic, remedial, or evaluative techniques that might be applied. Each block within the matrix contains a complete research project. For example, to develop remedial techniques (given that causes are known) to reduce the effects of disorientation and vertigo, one would implement block III. Implementation in this case means providing funding at the 5-year level of effort over 1 calendar year to investigate training, simulation, and job performance aids that may reduce disorientation/vertigo.

Each column of the matrix represents one phase of the overall research process; therefore, another option would be to perform diagnostic assessment for all selected pilot factors in one program. This concentrated effort assumes the existence of some general remedial strategy applicable to all pilot factors. Still another option would be to conduct a concentrated program of remedial research once the problem associated with each pilot factor have been adequately defined. This program, together with the general research strategy presented earlier, provides the content and structure for the proposed research program to follow.

Description of specific research projects--we will describe the 2-, 3-, and 5-year projects required by the contract. These projects are all constructed from the elements of research contained in Figure 6 and are structured similarly to the research program format in block IA. Projects to be discussed are listed below.

- A 2-year effort to provide diagnostic evaluation and problem definition for the pilot factor "excessive motivation to succeed."
- A 3-year effort to define the specific causal elements and provide remedial strategies for pilot overconfidence.
- A 5-year research project to provide diagnostics, remedial strategies, and preliminary evaluation of those strategies for disorientation/vertigo.

Following these descriptions, we will discuss a recommended research project.

PILOT FACTOR	PHASE I PROBLEM DEFINITION/DIAGNOSTICS 2-MAN-YEAR LOE 1-CALENDER-YEAR POP	PHASE II CONCEPT FORMULATION/REMEDIAL 1-MAN-YEAR LOE 1-CALENDER-YEAR POP	PHASE III EVALUATIVE 2-MAN-YEAR LOE 1-CALENDER-YEAR POP
(A) CHANNELIZED ATTENTION ASSOCIATED COST 140 M	(IA) <u>ATTITUDINAL MEASURES</u> • SAM STRESS BATTERY • HANDLING QUALITIES QUESTIONNAIRE • PANEL DESIGN INTERVIEWS <u>PHYSIOLOGICAL MEASURES</u> • HEART RATE • BP • EMG GSR • URINALYSIS • PUPIL DILATION • EEG <u>BEHAVIORAL MEASURES</u> • DUAL TASKING • COMPENSATORY TRACKING • VISUAL SCANNING (EXT)	(IIA) <u>TRAINING TECHNIQUES</u> • DUAL TRACKING • TIME ESTIMATION SHARING • SELECTIVE ATTENTION TRAINING <u>SIMULATION TECHNIQUES</u> • PART TASK • SCENARIO RE-CREATION • EMERGENCY PROCEDURES <u>JOB PERFORMANCE AIDS</u> • SELECTIVE ATTENTION MONITOR • TIME ESTIMATION GUIDE • DISTANCE JUDGMENT AIDS	(IIIA) <u>SIMULATOR EVALUATION</u> • BEHAVIORAL ANALOGUES • VIDEO GAMES • FULL SCALE HIFI SIMULATION <u>INSTRUMENTED RANGE</u> • STRAFING INTERDICTION • ACM 1 ON 1 • ACM M ON M <u>REAL WORLD TEST</u> • INTRODUCE REMEDIAL STRATEGY • MONITOR SELECT GROUPS • EVALUATE PROGRESS PER YEAR
(B) DISTRACTION ASSOCIATED COST 100 M	(IB) <u>ATTITUDINAL MEASURES</u> • SAM STRESS BATTERY • HANDLING QUALITY QUESTIONNAIRE • PANEL DESIGN INTERVIEWS <u>PHYSIOLOGICAL MEASURES</u> • HEART RATE • BP • EMG GSR • URINALYSIS • PUPIL DILATION • EEG <u>BEHAVIORAL MEASURES</u> • DUAL TASKING • COMPENSATORY TRACKING • VISUAL SCANNING (EXT)	(IIB) <u>TRAINING TECHNIQUES</u> • DUAL TRACKING • TIME ESTIMATION SHARING • SELECTIVE ATTENTION TRAINING <u>SIMULATION TECHNIQUES</u> • PART TASK • SCENARIO RE-CREATION • EMERGENCY PROCEDURES <u>JOB PERFORMANCE AIDS</u> • SELECTIVE ATTENTION MONITOR • TIME ESTIMATION GUIDE • DISTANCE JUDGMENT AIDS	(IIIB) <u>SIMULATOR EVALUATION</u> • BEHAVIORAL ANALOGUES • VIDEO GAMES • FULL SCALE HIFI SIMULATION <u>INSTRUMENTED RANGE</u> • STRAFING INTERDICTION • ACM 1 ON 1 • ACM M ON M <u>REAL WORLD TEST</u> • INTRODUCE REMEDIAL STRATEGY • MONITOR SELECT GROUPS • EVALUATE PROGRESS PER YEAR
(C) DISORIENTATION/VERTIGO ASSOCIATED COST 72 M	(IC) <u>ATTITUDINAL MEASURES</u> • NAVAL AVIATOR QUESTIONNAIRE • FIELD DEPENDENCY TEST • SAM STRESS BATTERY <u>PHYSIOLOGICAL MEASURES</u> • EEG • EVOKED POTENTIALS • EMG GSR <u>BEHAVIORAL MEASURES</u> • MAP/TERRAIN CORRELATION • SPATIAL ORIENTATION UNDER VERTIGO • INDIVIDUAL DIFFERENCES	(IIC) <u>TRAINING TECHNIQUES</u> • NAVIGATION (DEAD RECKONING) • INSTRUMENT DEPENDENCE • VERTIGO REDUCTION TECHNIQUES <u>SIMULATION TECHNIQUES</u> • VERTIGON TESTING • RE-CREATION OF DISORIENTATION • REORIENTATION PROCEDURES <u>JOB PERFORMANCE AIDS</u> • RELAXATION TECHNIQUES • ORIENTATING METHODS	(IIIC) <u>SIMULATOR EVALUATION</u> • SPIN TESTING TECHNIQUES • PART TASK SCENARIOS • FULL SCALE HIFI <u>INSTRUMENTED RANGE</u> • CREATE VERTIGO IN 2 PLACE AIRCRAFT RECOVERY • RE-CREATE CRITICAL MANEUVERS <u>REAL WORLD TEST</u> • INTRODUCE REMEDIAL STRATEGY • MONITOR SUCCESS OF SELECTED GROUPS
(D) EXCESSIVE MOTIVATION TO SUCCEED ASSOCIATED COST 54 M	(ID) <u>PERSONALITY INVENTORY</u> • WACH TESTING • YAI • UPT ATTRITION BATTERY • MMPI CRITICAL SCALES • ESSAY CONTENT ANALYSIS <u>BEHAVIORAL MEASURES</u> • SCENARIO ROLE PLAY • FOCUS GROUP BEHAVIOR • COMPETITION COGNITIVE PHYSICAL	(IID) <u>SELECTION</u> • MMPI BASED SELECTION BATTERY • WACH SELECTION • CRITERION REFERENCE TESTING <u>RETENTION</u> • COUNSELING • REALITY TESTING • ROLE PLAYING • DEVELOP EMS INDEX	(IIID) <u>SIMULATOR EVALUATION</u> • EVALUATE HI AND LO SUCCESS MOTIVATION GROUPS • DEVELOP SCENARIOS TO TEST EMS <u>INSTRUMENTED RANGE</u> • ESTABLISH EMS INDEX FOR PILOTS • MONITOR PERFORMANCE FOR HI AND LO GROUPS IN CRITICAL TASKS <u>REAL WORLD TEST</u> • INTRODUCE REMEDIAL STRATEGY • MONITOR ACCIDENT RATIO AMONG HI AND LO EMS PILOTS
(E) OVERCONFIDENCE ASSOCIATED COST 48 M	(IE) <u>ATTITUDINAL MEASURES</u> • ASSESS ATTITUDES TOWARD TRAINING • ASSESS ATTITUDES TOWARD EQUIPMENT • ASSESS ATTITUDES TOWARD RULES/REGS • OBTAIN OVERALL CONFIDENCE SCORE <u>BEHAVIORAL MEASURES</u> • ROLE PLAY SCENARIO • FOCUS GROUP BEHAVIOR • LEADERSHIP EVALUATION • COMPETITION COGNITIVE PHYSICAL	(IIE) <u>SELECTION</u> • TEST BASED ON SELF REPORT • PEER REPORT IN REGA. ADHERENCE TO RULES • ESTABLISH CONFIDENCE <u>RETENTION</u> • REALITY TESTING OF CONFIDENCE INDEX • ROLE PLAYS TO ESTABLISH OPTIMAL LEVEL • COUNSELING	(IIIE) <u>SIMULATOR EVALUATION</u> • DEVELOP SCENARIOS TO TEST CONFIDENCE • ESTABLISH HI AND LO CONFIDENCE GROUPS • EVALUATE PERFORMANCE <u>INSTRUMENTED RANGE</u> • DEVELOP REALISTIC SCENARIOS FOR CONFIDENCE ESTIMATION • RUN HI AND LO CONFIDENCE GROUPS <u>REAL WORLD TEST</u> • INTRODUCE REMEDIAL STRATEGY • MONITOR ACCIDENT RATIO FOR HI AND LO CONFIDENCE INVOLVEMENT

Figure 6. Technology applications.

A. Diagnostic Assessment of the Personality and Behavioral Variables Underlying Excessive Motivation To Succeed.
(Use block ID of Fig. 6.)

1. Purpose: The purpose of this research project is to identify, operationally define, and prioritize the underlying personality and behavioral characteristics associated with pilots described as being excessively motivated to succeed.

2. Approach/Products:

a. Task I: Review the literature and present applications regarding psychological assessment specific to success motivation issues. The product of this effort would be an annotated bibliography of applicable projective tests such as the McClelland Need for Achievement Test, the Thematic Apperception Test, the MMPI, and others from Boro's Mental Measurements Yearbook.

b. Task II: Review the literature and present applications regarding behavioral assessment techniques that could be used to define causal elements underlying success motivation. The product of this effort would be an annotated bibliography to include techniques such as role playing, competition, and focus groups.

c. Task III: Integrate most reliable/valid psychological and behavioral techniques with regard to implementation cost and feasibility. The product of this effort would be a menu of diagnostic batteries specifically tailored to the issue of success motivation.

d. Task IV: Apply most feasible and cost-effective diagnostic battery to a representative sample of pilots who display excessive motivation to succeed. The product of this task would be the identification and operational definition of the variables underlying success motivation. These definitions would provide the objectives for remedial strategies.

3. Schedule and Level of Effort: The project described above would require funding at the 2-manyear level of effort and would be performed over 1 calender year. The project schedule is shown in Figure 7.

B. Diagnostics and Remedial Strategies for the Personality and Behavioral Factors Underlying Pilot Overconfidence.
(Use Blocks 1E and IIE of Fig. 6.)

1. Purpose: The purpose of this research project is to diagnose and provide remedial techniques for the underlying psychosocial characteristics associated with pilots identified as overconfident.

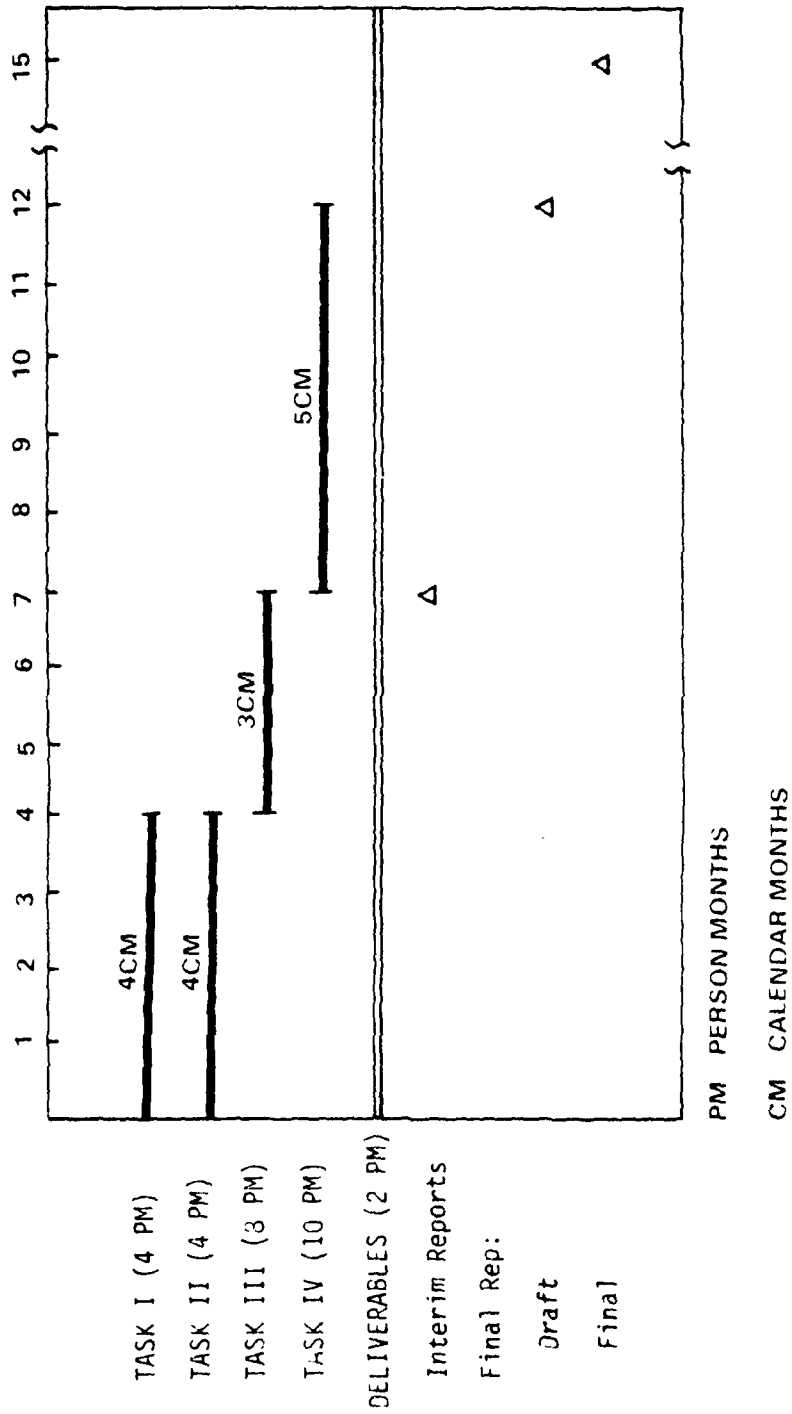


Figure 7. Project schedule for diagnostic assessment of excessive motivation to succeed.

2. Approach and Products

• Phase 1--Diagnostic Assessment

a. Task I: Review the literature and present applications regarding psychological assessment specific to overconfidence issues. The product of this effort would be an annotated bibliography of 1) applicable projective tests and attitude-measurement techniques including MMPI, Thematic Apperception Test, and measures of attitudes toward equipment; 2) regulations; and 3) training techniques.

b. Task II: Review the literature and present applications regarding behavioral assessment of self-confidence by role play, focus groups, leadership evaluation, and competitive scenarios. The product of this review would be a list of selected assessment techniques with high construct validity in regard to the mission management duties of a pilot.

c. Task III: Integrate most reliable/valid psychological and behavioral techniques with regard to implementation cost and feasibility. The product of this effort would be a menu of diagnostic batteries specifically tailored to the issue of overconfidence and guided by a representative mission scenario.

d. Task IV: Apply most feasible and cost-effective diagnostic battery to a representative sample of aviators who display overconfidence. The product of this task would be the identification and operational definition of the psychosocial variables underlying overconfidence. These definitions would provide the objectives for remedial strategies based on a pilot-confidence index.

• Phase 2--Remedial Strategy Development

a. Task I: Review potential remedial strategies in personnel selection/retention/reliability literature. This review will be guided by the pilot-confidence index derived from the Phase 1 diagnostics. The product of this task will be a list of potential remedial techniques related to specific underlying psychosocial variables. This list will be rank ordered with regard to both feasibility and cost effectiveness.

b. Task II: Validate the pilot-confidence index against behavioral criteria during controlled, risk-taking situations. Select most effective remedial strategy with which to apply an index of this type. The product of this task would provide the objectives from which to conduct a program to reduce the negative effects of overconfidence.

c. Task III: Develop a prototype remedial program including pilot-selection techniques, continuous behavioral observation, intermittent psychosocial assessment, self-reporting, and remedial counseling/reassignment. The product of this task would emphasize a central measure of pilot confidence which would guide selection, retention counseling, or reassignment.

3. Schedule and Level of Effort: The project described above would require funding at the 3-man-year LOE and would be performed over 2 calendar years. The project schedule is shown in Figure 3.

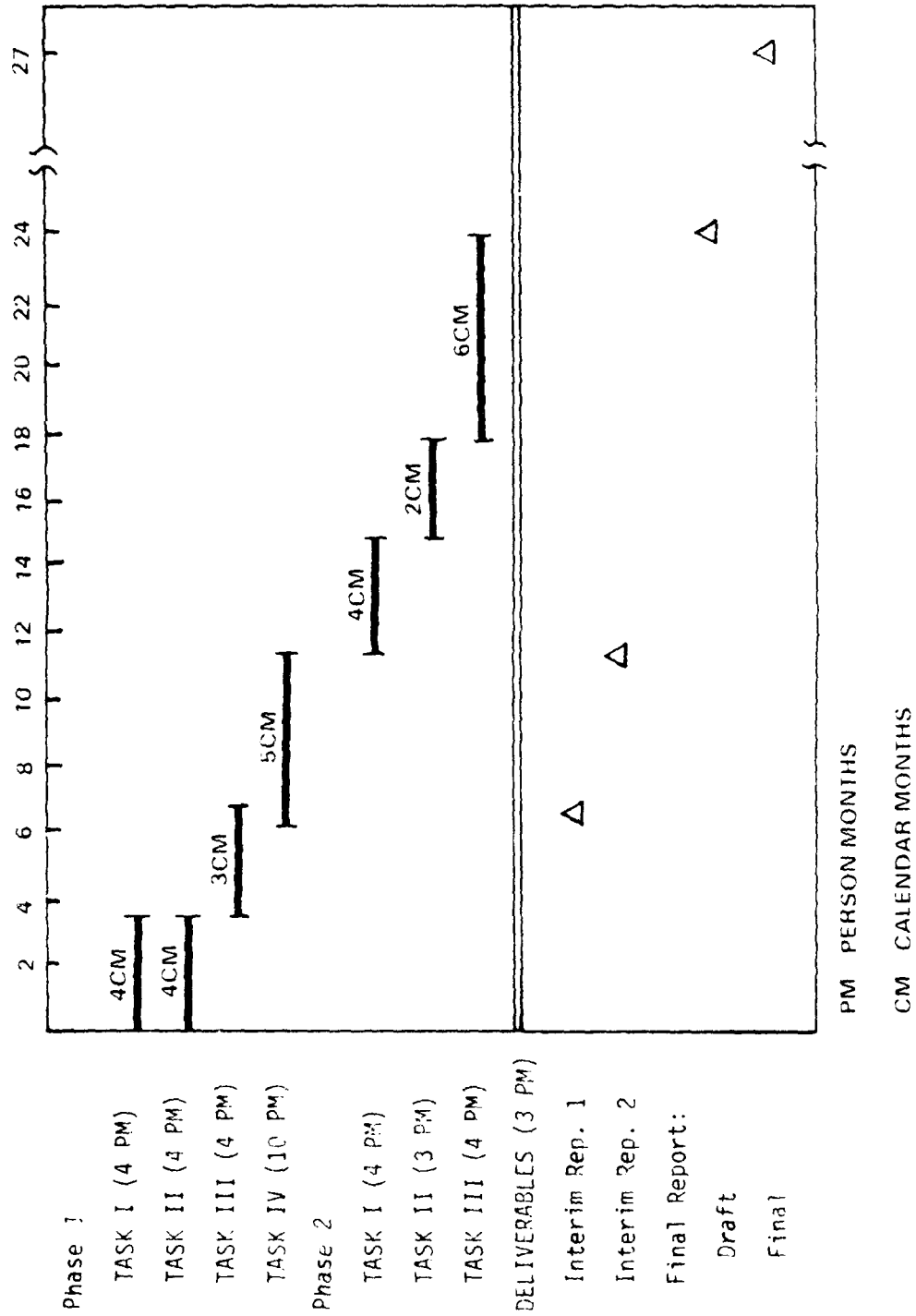


Figure 3. Project schedule for diagnostic assessment of and remedial strategies for factors underlying pilot overconfidence.

C. A Diagnostic, Remedial, Evaluative Approach to the Reduction of Disorientation/Vertigo Among Air Force Pilots. (Use blocks 1C, 11C, and 111C of Fig. 6).

1. Purpose: The purpose of this project is to identify and define the underlying psychological, physiological, and behavioral characteristics that are associated with pilot disorientation and vertigo. In addition, this project will provide prototype remedial strategies and an operationally oriented test and evaluation paradigm.

2. Approach/Products:

• Phase 1--Diagnostic Evaluation

a. Task I: Conduct literature review on psychological assessment of tendencies toward spatial and temporal disorientation. Assessment techniques might include the Naval Aviation Questionnaire, the SAM Stress Battery, and the Witkens Embedded Figures Test. The product of this task will be a list of candidate techniques ranked in regard to validity and feasibility.

b. Task II: Conduct state-of-the-art review of physiological measurement techniques to assess disorientation or vertigo susceptibility. Such measures might include cortical-evoked potentials, electromyogram, and galvanic skin response (GSR). The product of this task will be a list of candidate physiological measures selected for feasibility, validity, and cost effectiveness.

c. Task III: Conduct review of existing behavioral measures of disorientation/vertigo susceptibility. Such measures could include orientation (terrain walks), road-rally-type exercises, or reorientation subsequent to vertigo induction. The result of this effort will be a list of behavioral techniques ranked with regard to feasibility and validity.

d. Task IV: Cross validate the three classes of disorientation/vertigo measures by conducting quasi experiments on a representative sample of Air Force pilots. The product of this task will be a list of composite measures of disorientation/vertigo ranked in regard to the magnitude of the inter-correlation among measures.

e. Task V: Select battery of psychological, physiological, and behavioral measures exhibiting the highest degree of relationship among themselves. Apply these measures as dependent variables in a controlled experiment using a representative disorientation/vertigo-induction technique on a random sample of Air Force pilots. The product of this task will be the identification and operational definition of the psychological, physiological, and behavioral variables underlying disorientation/vertigo. In addition, this task will provide a valid and reliable measurement battery for possible application to related phenomena.

• Phase 2--Remedial Strategy Development

a. Task I: Based on diagnostic assessment and resulting operational definitions of disorientation/vertigo, conduct literature review into

available remedial strategies in the technology areas of aircrew training, simulation, and job performance aids. This will provide a list of remedial techniques from the three major technology areas. This list, together with the diagnostic measures, could be used to guide the development of a "best case" remedial approach.

b. Task II: Integrate selected remedial strategies into composite solution approaches relating to the specific results of diagnostic assessment. This effort will provide a menu of selected approaches that represent contributions from the three technology areas. The approaches will be ranked in regard to feasibility in relation to the diagnostic results and cost effectiveness.

c. Task III: Select most effective remedial approach from the menu above in regard to results from the diagnostic phase, cost effectiveness, and feasibility.

● Phase 3--Evaluation

a. Task I: Design and implement simulator scenarios that induce disorientation/vertigo ranging from part task to high-fidelity simulation. Conduct experiments applying selected remedial strategies as independent variables (treatment) and diagnostics as dependent measures. The results of these experiments will be used to provide guidance for subsequent evaluation tasks and to refine the selection of remedial approach.

b. Task II: Based on the results of Task I, select most promising remedial strategy and most valid/reliable measurement system and evaluate both experimentally in an instrumented range environment by creating disorientation/vertigo situations in two-place aircraft. (Subject operates in observer position.) The results of these experiments will be fed back to further refine the approach prior to introduction.

c. Task III: Introduce selected remedial technique in a limited fashion into undergraduate and advanced pilot training where applicable. Monitor subsequent accident rates of a selected sample of new pilots with regard to disorientation/vertigo as a pilot factor. The results of these observations will be fed into the pilot-factor data base to help project trends in aircraft mishaps and to guide future technology-application programs.

3. Schedule and Level of Effort: The project described above would require funding at the 5-man-year level of effort and would be performed over 3 calendar years. The project schedule is shown in Figure 9.

The three projects just described represent the end product of this systematic approach to program development. The 2-, 3-, and 5-man-year programs fulfill the contractual requirements for programs with a high selection potential by the in-house staff. These projects are based on existing diagnostic, remedial, and evaluation techniques within the reach of USAFSAM personnel.

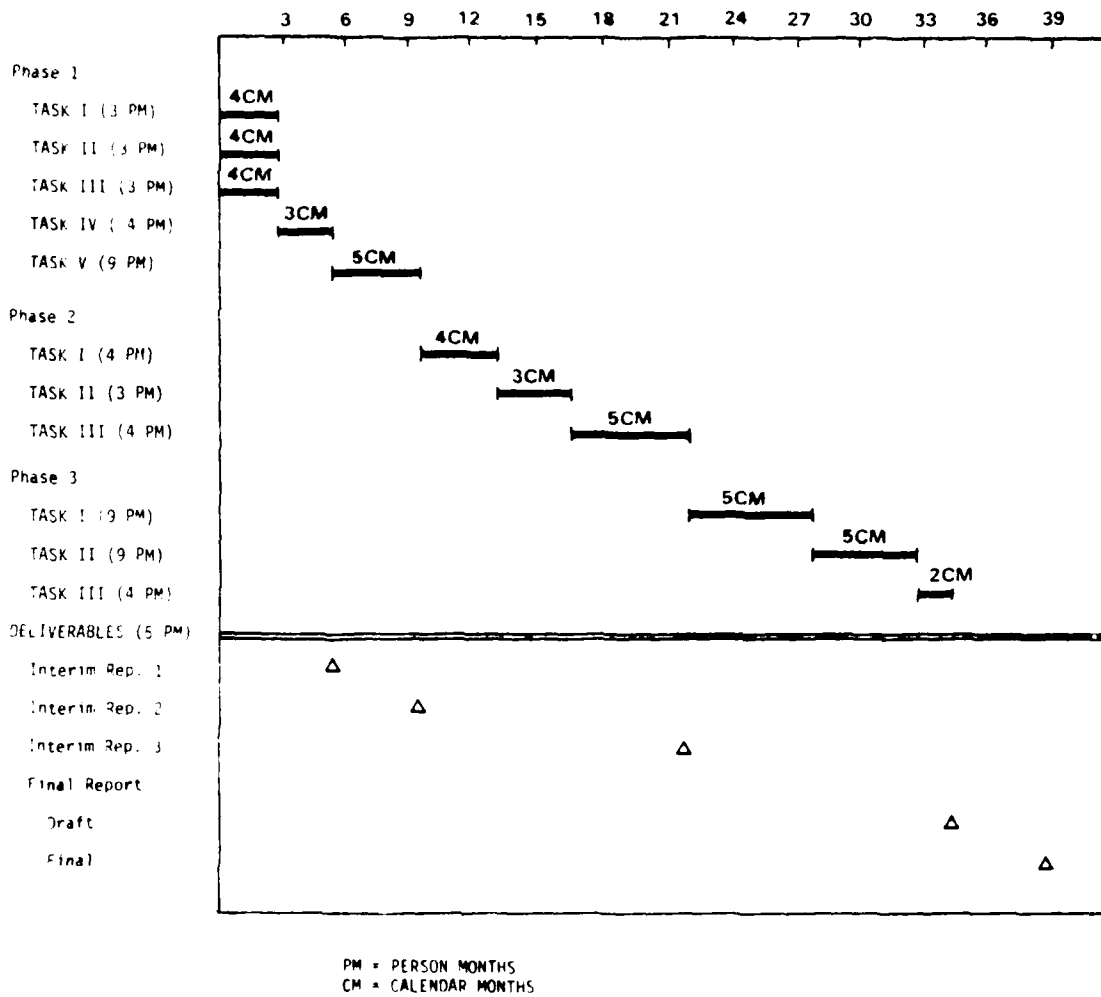


Figure 9. Project schedule for a diagnostic, remedial, evaluative approach to reducing disorientation/vertigo among Air Force pilots.

In the following section, we recommend a project of technology applications that are believed to be the most cost effective and potentially rewarding of all the options.

Recommended Research Project

The following research project is designed to apply a diagnostic assessment, remedial approach, and operational evaluation to the problems associated with channelized attention and distraction. Based on the data we examined, these pilot factors are the two that occur most often in fighter, attack, and trainer aircraft mishaps. Together they were associated with \$254 million in mishap cost over the period 1977-78. Based on our research described in Sections II and IV, we have concluded that channelized attention and distraction are really opposite sides of the same coin. Both are essentially concerned with allocating attention to a stimulus. Channelized attention means that a pilot continues to focus attention on one stimulus although another stimulus of more immediate priority should be attended. For example, during a bombing run, a pilot may continue to focus his attention on target acquisition or even on the bomb trace created on the ground instead of on maintaining flight position control.

Distraction, on the other hand, means that a pilot's attention is diverted from one stimulus to another. For example, the pilot may be on a bombing mission when an object apparently appears outside the cockpit or a light flashes on the instrument panel. The pilot may pay attention to this stimulus and fail to refocus on the tasks required to maintain positive flight control.

Neither channelized attention nor distraction are inherently problematic. They become problems during flight when the pilot's time to respond to situational demands is brief. We believe that an integrated research effort attacking channelized attention and distraction simultaneously has the most potential for success and the highest return on investment. This project is based on the underlying construct of allocating attention in a time-compressed situation and is described as follows:

A Programmatic Approach to the Reduction of Pilot-Factor Mishaps Associated with Attention Allocation (Use blocks IA, IIA, IIIA, IB, IIB, and IIIB from Fig. 6.)

1. Purpose: The purpose of this recommended project is to use valid and reliable diagnostics upon which to base the development and evaluation of mishap reduction strategies aimed at the two major pilot factors, channelized attention and distraction.

2. Approach and Products:

• Phase 1--Diagnostic Assessment. This phase reflects a multidisciplinary check-and-balance research philosophy.

a. Task I: Review the psychological-assessment literature in order to develop/adopt diagnostics specific to the phenomenon of attention allocation. Assessment techniques in the area of stress perception, aircraft handling qualities, and aircrew station design will be considered.

- (1) Subtask 1. Define literature-search strategy in terms of scope, sources, time period, and key words.
- (2) Subtask 2. Review, in depth, selected articles, books, and ongoing research, using search tactics derived from standard abstract forms.
- (3) Subtask 3. Develop and apply criteria for ranking assessment methods by feasibility and cost effectiveness.
- (4) Product: The product of this task will be a rank-ordered list of psychological-assessment techniques that will be used to develop a multidisciplinary diagnostic battery.

b. Task II: Review the literature dealing with physiological measurement of attention and performance so that existing techniques can be adopted to assess attention allocation in airborne mission management.

- (1) Subtask 1. Define and apply parameters of the literature search strategy including scope, sources, time period, and key words.
- (2) Subtask 2. Review in depth selected journal articles, books, and ongoing research efforts in areas related to measurement of attention under stress. These areas might include cortical-evoked potentials, pupil dilation, electromyogram, GSR, and heart rate.
- (3) Subtask 3. Develop and apply criteria for ranking physiological assessment techniques in regard to real-world application, validity, reliability, and cost effectiveness.
- (4) Product. The product of this task will be a rank-ordered list of physiological measurement techniques that could be used as part of a battery to assess attention under stress.

c. Task III: Review the literature concerning behavioral measures of attention and performance, including techniques such as dual tasking, residual attention capacity, and stress-induction methods.

- (1) Subtask 1. Define and apply literature search strategy including scope, sources, time period, and key words.
- (2) Subtask 2. Review in depth selected articles, books, and ongoing research. Concentrate on areas such as information processing, hot cognition, artificial intelligence, and memory structure.

- (3) Subtask 3. Develop and apply criteria for ranking behavioral assessment methods according to feasibility, validity, and cost effectiveness.
- (4) Product. The product of this task is a list of assessment techniques based on behavioral observation and ranked in regard to operational consideration. This list will be used in conjunction with the psychological and physiological measures in Task IV.

d. Task IV: Cross-validate high-ranking attention allocation measures in psychological, physiological, and behavioral assessment described in Tasks I, II, and III.

- (1) Subtask 1. Design and perform quasi experiments on a small representative sample of Air Force pilots to provide preliminary data for technique validation.
- (2) Subtask 2. Perform multiple correlation and regression analysis on results of the validation studies to determine the strength of relationships among measurement techniques.
- (3) Subtask 3. Construct a list of composite attention measures rank ordered by strength of relationship, cost of implementation, and feasibility.
- (4) Product. The product of this task will be recommended attention-assessment batteries.

e. Task V: Select and refine the most promising multidisciplinary assessment battery.

- (1) Subtask 1. Choose the combination of psychological, physiological, and behavioral measures that exhibit the highest degree of interrelationship among the measures.
- (2) Subtask 2. Apply this assessment battery as dependent measures in a controlled experiment using a mission-based, attention-allocation task and a representative sample of Air Force pilots.
- (3) Subtask 3. Feed back the result of this experiment in order to refine and specify the measurement battery in regard to mission objectives. Input results to pilot-factor-mishap data base.
- (4) Product. The product of this task, and of Phase I, will be the identification and precise operational definition of psychological, physiological, and behavioral variables underlying attention allocation. This effort will also provide a valid and reliable measurement battery for future application to this attention factor and related phenomena.

• Phase 2--Remedial Strategy Development. Based on systems integration approach; i.e., requirements vs capabilities.

a. Task I: Conduct literature reviews of remedial techniques guided by results of diagnostic assessment.

- (1) Subtask 1. Define and apply literature search strategy with regard to variables identified from the diagnostic phase.
- (2) Subtask 2. Review selected articles, books, and ongoing research in the content areas of aircrew training, simulation, and job performance aids.
- (3) Subtask 3. Develop and apply criteria for ranking remedial techniques according to feasibility, validity, and cost effectiveness.
- (4) Product. The product of this task will be a matrix composed of rank-ordered techniques in remedial technology areas of aircrew training, simulation, and job performance aids. This matrix and the result of the diagnostics will be used to guide further development of a best-case remedial strategy.

b. Task II: Integrate attention-allocation remedial strategies from technology areas of training, simulation, and job performance aids.

- (1) Subtask 1. From the three technology areas, choose promising remedial techniques based on operational criteria.
- (2) Subtask 2. Combine selected techniques from Subtask 1 as guided by the result of the diagnostic assessment.
- (3) Product. The product of this task will be a list of the three most promising remedial approaches to the reduction of attention-allocation mishaps.

c. Task III: Select optimal remedial strategy using a quasi experiment.

- (1) Subtask 1. Select/adopt representative mission scenario related to attention allocation.
- (2) Subtask 2. Design/perform a quasi experiment around mission scenario, using remedial strategies as independent variables and diagnostic battery as dependent measures.
- (3) Subtask 3. Analyze data from experiment and select most effective and reliable remedial approach.
- (4) Product. The product will be a best-case remedial approach based on empirical research findings, operational feasibility, and potential return on investment.

• Phase 3--Evaluation. This phase is based on a successive-approximations approach to evaluation under operational conditions.

a. Task I: Design/conduct simulator experiments to evaluate remedial approach.

- (1) Subtask 1. From operational missions, design or adopt specific scenarios that produce situations associated with attention-allocation problems.
- (2) Subtask 2. On sizable, representative sample of Air Force pilots, conduct controlled experiments designed around mission scenarios. Employ remedial strategy as independent variables and diagnostic battery as dependent measures.
- (3) Subtask 3. Collect, reduce, and analyze data, then input to pilot-factor-mishap data base.
- (4) Product. Results of these experiments will provide guidance to subsequent evaluative tasks and refinement to the remedial approach and investigation process.

b. Task II: Based on results of Task I, subject refined remedial strategy or alternate remedial strategy to instrumented range evaluation.

- (1) Subtask 1. Design or adopt scenarios from Task I to specific requirements of instrumented range simulation. Arrange administrative details.
- (2) Subtask 2. On stringently selected sample of Air Force pilots, conduct controlled experiments designed around mission scenarios shown to produce attention-allocation problems. Use remedial strategy as treatment, and diagnostic battery as dependent measures. Record missions for future analysis.
- (3) Subtask 3. Collect, reduce, and analyze data and input to pilot-factor-mishap data base.
- (4) Product. The result of these experiments will be fed back to further refine the remedial approach prior to introduction and will be input to the data base.

c. Task III. Plan the introduction of remedial approaches to reduce attention-allocation mishaps.

- (1) Subtask 1. Plan the integration of the new remedial approach with undergraduate and advanced pilot-training curricula according to interservice procedures for Instruction System Development.
- (2) Subtask 2. Design a procedure to monitor subsequent mishap and near-mishap rates for a selected sample of pilots over a 5-year period.

(3) Product. The product of Task III, and Phase III, will be a plan for introducing the refined remedial approach, to be implemented by the Air Force.

3. Schedule and Level of Effort: The recommended approach to reducing mishaps associated with channelized attention and distraction would require funding at the 7-man-year level of effort. It would be conducted over 39 calendar months with a 3-month report-evaluation period included. The hypothesis that channelized attention and distraction are two aspects of attention allocation enables their simultaneous investigation at a level of effort lower than would be required for two separate investigations. The project schedule and resource allocations are illustrated in Figure 10.

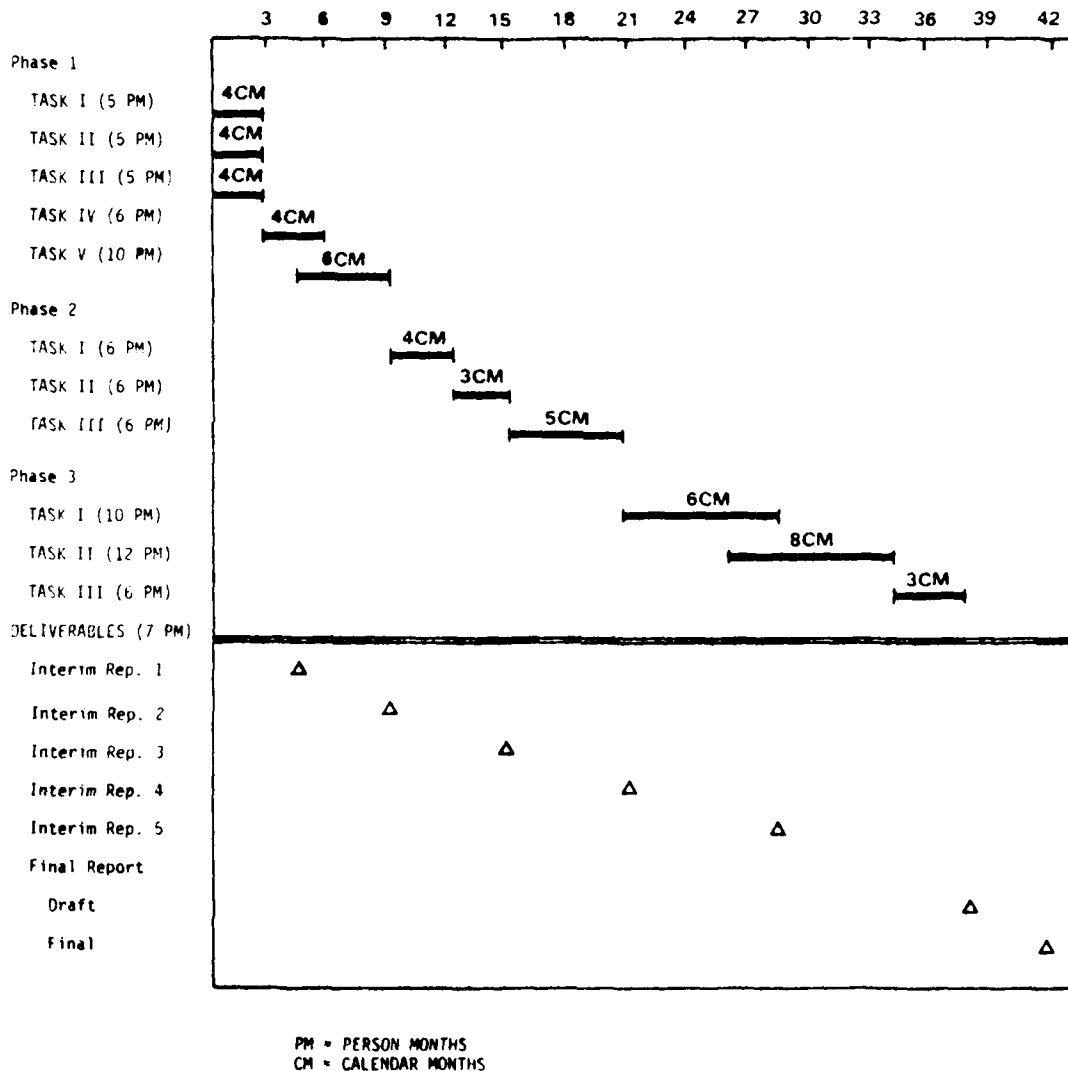


Figure 10. Project schedule for a programmatic approach to reducing pilot-factor mishaps associated with attention allocation.

APPENDIX A. LITERATURE SEARCH STRATEGY AND ANNOTATED REFERENCES

Much of the information contained in this report was obtained from literature in the field of aviation safety. The major focus of this review was the pilot-factor causes of aircraft mishaps and current aviation technologies that have potential for reducing or eliminating mishaps due to these causes.

Most of the literature is contained in unpublished government reports or published professional journals, primarily in the fields of psychology and human factors. This appendix describes how the specific articles (reviewed in Sections 2 and 4) were selected and reviewed, and provides annotated references used in this report.

Sources and Search Strategy

Sources--Two major sources were examined, the National Technical Information Service (NTIS) and the Psychological Abstracts. The former source contains abstracts of over one million reports from a number of government agencies. The latter reviews and abstracts articles from nearly 600 professional journals and reports.

Table A-1 presents keywords used to scan the holdings of each source. For the NTIS search, combinations of keywords were used. This is reflected by first-level and second-level search terms in which each first-level term is searched by itself and in combination with a second-level search term. Different keywords were used for NTIS and Psychological Abstracts since the two sources have different keyword-retrieval mechanisms. The review was confined primarily to articles and reports written during the 1970's.

In addition to these major sources, three other sources of materials were scanned.

- (1) Human Factors, the journal of The Human Factors Society, for the period 1970-79. This journal frequently publishes articles on aviation safety.
- (2) The Annual Proceedings of The Human Factors Society, for the meetings in 1978 and 1979.
- (3) Selected popular magazines and newspapers, including the U.S. Army Aviation Digest, Air Force Magazine, Aviation and Space Technology, Air Force Times, and the Army Times.

Search Strategy--Three passes were made through the literature. The first pass was a keyword search of NTIS and Psychological Abstracts and a review of the other sources on the basis of which a number of articles and reports were selected. Second, the abstract, introduction, and conclusion sections of each article were read to see if the article pertained to either pilot-factor causes of mishaps or the technologies available to remedy these mishaps. Third, articles that were selected on the basis of this pass were read in depth.

TABLE A-1. KEYWORDS USED TO SCAN NTIS AND PSYCHOLOGICAL ABSTRACTS

PSYCHOLOGICAL ABSTRACTS
KEYWORDS

NTIS KEYWORDS

SEARCH 1

FIRST-LEVEL SEARCH TERMS
ACCIDENT INVESTIGATION
AVIATION SAFETY
SECOND-LEVEL SEARCH TERMS
ATTENTION
DISTRACTION
ENDURANCE (PSYCHOLOGY)
FATIGUE (PSYCHOLOGY)
HEAT STRESS (PSYCHOLOGY)
HUMAN ERROR
HUMAN FACTOR
OVERLOAD
PILOT ERROR
PREVENTION
STARVATION
STRESSES
STRESS (PSYCHOLOGY)
STRESS (PSYCHOLOGY)
VERTIGO
WATER PRIVATION

SEARCH 3

FIRST-LEVEL SEARCH TERMS
ACCIDENTS
AIRCRAFT ACCIDENT
AIRCRAFT COLLISION
AIRCRAFT CRASH
SECOND-LEVEL SEARCH TERMS
AERIAL GUNNERS
AIR TRAFFIC CONTROL SYSTEMS
AIR TRAFFIC CONTROL TERMINAL AREAS
AIR TRAFFIC CONTROLLERS
AIRCRAFT LANDINGS
AIRPORT CONTROL TOWERS
AIRPORT CONTROL SYSTEMS
AIRPORTS
AVIATION ACCIDENTS
AVIATION PERSONNEL
AVIATION TECHNICIANS
CARRIER-CONTROLLED APPROACH RADAR
CRASH LANDINGS
DITCHING
FLIGHT SURGEONS
GLIDE PATH SYSTEMS
GLIDE SLOPE
GROUND-CONTROLLED APPROACH RADAR
INSTRUMENT LANDINGS
LANDING FIELDS
LANDING MATS
NAVIGATOR BOMBARDIERS
NIGHT LANDINGS
PILOTS
RADAR LANDING CONTROL
RUNWAYS
TAXIWAYS
TERMINAL FLIGHT FACILITIES

SEARCH 4

FIRST-LEVEL SEARCH TERMS
COLLISION
COLLISION AVOIDANCE
SECOND-LEVEL SEARCH TERMS
AEROSPACE CRAFT
AEROSPACE PLANES
AIR CUSHION VEHICLES
AIRCRAFT
AIRPLANES
AIRSHIPS
ALL WING PLANES
ANTISUBMARINE AIRCRAFT
ARMY AIRCRAFT
ATTACK AIRCRAFT
ATTACK BOMBERS
ATTACK HELICOPTERS
AUTOGYROS
BALLOONS
BOMBER AIRCRAFT
BOOST GLIDE VEHICLES
CARRIER-BASED AIRCRAFT
COMMERCIAL AIRCRAFT
COMPOSITE PLANES
CONVERTIBLE PLANES
DOWNED AIRCRAFT
DRONE CONTROL PLANES
DRONES
ELECTRONIC AIRCRAFT
FIGHTER AIRCRAFT
FIGHTER BOMBERS
FLYING BOATS
FLYING PLATFORMS
GLIDERS
GROUND EFFECT MACHINES
GUNSHIPS
HELICOPTERS
HYPERSONIC AIRCRAFT
JET AIRCRAFT
JET BOMBERS
JET FIGHTERS
JET FLYING BOATS
JET SEAPLANES
JET TRAINING PLANES

ACCIDENT PREVENTION
AIRCRAFT PILOTS
AIR TRAFFIC ACCIDENTS
ATTENTION
DISTRACTION
FATIGUE
HUMAN CHANNEL CAPACITY
HUMAN-FACTOR ENGINEERING
PSYCHOLOGICAL STRESS
TASK OVERLOAD
VERTIGO
WORKLOAD

JET TRAINING PLANES
METEOROLOGICAL BALLOONS
MILITARY AIRCRAFT
NAVAL AIRCRAFT
OBSERVATION AIRCRAFT
PARASITE PLANES
PASSENGER AIRCRAFT
PATROL AIRCRAFT
RECONNAISSANCE AIRCRAFT
REMOVELY PILOTTED VEHICLES
RESEARCH AIRCRAFT
RESEARCH PLANES
ROCKET PLANES
ROTARY WING AIRCRAFT
SEAPLANES
SHORT-TAKEOFF AIRCRAFT
SUPERSONIC AIRCRAFT
SUPERSONIC TRANSPORTS
SURVEILLANCE DRONES
TACTICAL AIRCRAFT
TAILLESS PLANES
TANKER PLANES
TARGET DRONES
TOWED PLANES
TOWING PLANES
TRAINING PLANES
TRANSONIC AIRCRAFT
TRANSPORT AIRCRAFT
UTILITY AIRCRAFT
VERTICAL-TAKEOFF AIRCRAFT
WATER-BASED PLANES

SEARCH 2

FIRST-LEVEL SEARCH TERMS
AVIATION ACCIDENTS
SECOND-LEVEL SEARCH TERMS
ATTENTION
DISTRACTION
ENDURANCE (PSYCHOLOGY)
HEAT STRESS (PSYCHOLOGY)
OVERLOAD
PREVENTION
STARVATION
STRESSES
STRESS (PSYCHOLOGY)
STRESS (PSYCHOLOGY)
VERTIGO
WATER PRIVATION

The reading of these articles was guided by an abstracting form (Exhibit B-2, Appendix B). The form was developed to insure that the reviewers abstracted reliable, relevant information from the articles. The most useful of these articles are cited in the body of this report and in the following annotated references.

Annotated References

1. Alkov, R. A. Life changes and accident behavior. Approach, pp. 18-20, Feb 1975.

This report concludes that the majority of accident behavior can be explained by personal stresses that cause a person to perform in such a manner as to increase his or her accident liability. A tabular presentation is given of lifestyle changes during deployment for Naval officers. The total effect of these changes is thought to tax the aviator's ability to cope.

2. Alkov, R. A. Personality characteristics of the high-accident-risk Naval aviator. Unpublished manuscript. Naval Safety Center, Norfolk Naval Air Station, Norfolk, Virginia, Nov 1976.

A behavioral analysis was made of fatal pilot-error aircraft accidents in the U.S. Navy during fiscal years 1975 and 1976. A 43-item recent life-changes questionnaire, developed by Dr. Thomas Holmes and Captain Richard Rahe, was sent to squadrons reporting fatal pilot-error accidents for completion by survivors. A dozen pilot-error accidents involving pilots with personality profiles resembling those described by Reinhardt (1966) were identified from the completed questionnaires and from the medical officer's reports of aircraft accidents. Most were due to flight violations on the part of the pilot.

3. Alnutt, M. F. The psychologist's role in aircraft accident investigations. In K.G.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

The article concludes that psychologists can make three contributions to the reduction of human-error aircraft accidents: (1) analysis of human-error accident data, (2) research on human-factor aspects of flight safety, and (3) contribution to accident investigation. The RAF Institute of Aviation Medicine engaged a long-term study of the usefulness of the third type of activity. This approach to improving flight safety makes use of information and techniques from the fields of applied experimental psychology, organizational psychology, ergonomics, and clinical psychology, and it is hoped will result in a reduction of aircraft accidents. As a result of the inquiry, changes to the cockpit layout, the method of operation of equipment, and the design of the organizational system were recommended.

4. Bateman, R. P. Investigation of pattern recognition of aircraft attitude indicator display. Wright-Patterson AFB, Ohio: Air Force Institute of Technology, Master's thesis, June 1973.

Spatial disorientation accident statistics and unsuccessful attempts to prevent these aircraft accidents are reviewed. The lack of a theoretical basis for flight instrument design is noted. A systems approach to the problem is proposed, which requires a knowledge of the human visual system. It is suggested that attitude indicator displays, the interface between man and machine, should be designed to be compatible with an internal model of spatial position. Orientation in space by the use of flight instruments is identified as a pattern recognition problem. A Fourier transform model of the human visual system is used to evaluate and classify attitude indicator displays. An algorithm is proposed for separating patterns with respect to a single characteristic. Results of this experiment show that the fixed and moving horizon displays are mapped into opposite halves of the linear decision space. This discovery is the basis for a prediction that the human operator may commit errors of reversal when using the moving horizon display. The predicted reversals have been reported as results of an in-flight experiment. The filtered Fourier transform model results, in agreement with psychophysical phenomena, are found to provide a basis for instrument design.

5. Bergin, K. G. The effects of fatigue on health and flight safety. *Airline Pilot*, July 1976.

A conceptual review of fatigue, health, and flight safety is presented. The author appears knowledgeable, but no data are presented. Responsibility, mental load, physical overload, and psychological factors are discussed.

6. Bergman, C. A. An airplane performance control system: A flight experiment. *Human Factors* 18(2):173-182 (1976).

Pilot performance and preference measures were obtained for 12 pilots in actual flight operations using a twin-engine general aviation aircraft with both conventional controls and a Performance Control System (PCS). The PCS provides zero-order control of aircraft bank angle and vertical speed over the ranges of ± 60 and ± 457.2 m/min, respectively. An information-processing side-task was also used. With the PCS, flight error scores were reliably lower than with conventional aircraft controls. Pilot preferences, using a six-point scale ranging from "slight" to "moderate" to "strong" preference for each of the two control systems, showed a moderate preference for the PCS as the median response.

7. Beringer, D. B., et al. The transition of experienced pilots to a frequency-separated aircraft attitude display. *Human Factors* 17(4): 401-414 (1975).

Independent groups of eight navy pilots each were given one flight in a Link GAT-2 simulator and one flight in a Beechcraft C-45H using the moving horizon, moving airplane, and frequency-separated attitude displays. The flight tasks performed by the subjects included recovery from unknown attitudes, disturbed attitude tracking, and completion of an area navigation course. Data collected in the C-45H aircraft demonstrated superior performance of both the frequency-separated and moving horizon displays when compared to the moving airplane display during unknown attitude recoveries. The frequency-separated display was superior to all others during disturbed attitude tracking. It was concluded that the flight performance of experienced pilots during

their initial transition to a frequency-separated flight attitude presentation is at least comparable, and for some tasks superior, to their flight performance with the conventional moving horizon presentation.

8. Bermudez, J. M., et al. Peripheral vision and tracking performance under stress. Proceedings of The Human Factors Society 23rd Annual Meeting, pp. 402-406. Santa Monica, California: The Human Factors Society, Inc., 1979.

The complexity of modern aircraft systems places substantial information-processing loads on the pilot. These loads are exacerbated during periods of cognitive and emotional stress such as during emergency landing situations. Physiological and behavioral evidence for two human visual systems that may differ in susceptibility to psychological stress suggests the possibility of a natural stress-resistant information channel that could be used to input information during stressful flight situations. It follows that the extreme peripheral visual fields could be a possible location for adjunct visual displays that serve to orient expeditiously the pilot's focal vision and attention to critical instrument displays during emergencies or other situations.

This report presents data on two followup experiments involving 46 male cadets. The data concern the effects of three types of instrument displays used under varying levels of stress during a simulated instrument landing. Stress was defined as demand for primary task-related cognitive activity. A modified Sternberg memory probe technique was used to impose these demands.

9. Berry, J. R., and S. L. DeLoach. A statistical analysis of selected human factors involved in aviation safety. Wright-Patterson AFB, Ohio: Air Force Institute of Technology. Technical Report No. LSSR 6-784, 1978.

This report presents a review of the biorhythm theory and a statistical analysis on over 2400 aviation accidents, obtained from the Army Aviation Safety Center, Fort Rucker, Alabama. The analysis was performed to determine if a statistically significant relationship existed between aviation accident dates and biorhythm caution days. The Binomial Goodness-of-Fit Test was applied against the data. No significant relationship was found between the aviation accidents and biorhythm caution days.

10. Collins, W. E. Disorientation training in FAA certified flight and ground schools: A survey. Washington, D.C.: FAA Office of Aviation Medicine. Report No. AM-77-24, Sep 1977.

A 10-item, voluntary questionnaire answered by 674 flight and ground schools provided information on (1) the conduct of formal instruction about disorientation, (2) the occurrence and content of lectures on disorientation, (3) use of on-the-ground demonstrations of disorientation, (4) use of in-the-air demonstrations of disorientation, (5) use of films on pilot vertigo, (6) amount of instrument-flying training students receive, (7) amount of instrument-flying training required of flight instructors to maintain their proficiency, (8) adequacy of the school's program on disorientation training, (9) other comments, and (10) numerical data regarding the number of students beginning and completing various flight and/or ground school courses.

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More than one-third of the respondents evaluated their disorientation training program as inadequate and defined the inadequacy most often as a lack of appropriate materials, aids, and information. Tabulations of responses to the separate items suggested areas for improvement in disorientation training. Recommendations were made.

11. Collins, W. L. Effective approaches to disorientation familiarization for personnel. Washington, D.C.: FAA Office of Aviation Medicine. Report No. AM-70-17, Nov 1970.

The purpose of the report is to explain an approach to familiarizing aviation personnel with the hazards of disorientation and to provide suggestions for use in other training programs. The methodology is not designed to train pilots so that they will be immune to disorientation problems, but only to familiarize them with many of the unusual and false perceptions of vestibular origin that can occur in flight and to impress upon them the importance of obtaining an instrument rating and maintaining instrument proficiency.

A modification of a rotating device (motor-driven rotating chair) is used to simulate aircraft motion. A pilot sits in the chair, others observe. Room lights are turned off and the pilot can see only "approaching aircraft," framed through his "window." Smooth clockwise acceleration is applied, then constant turning velocity. The pilot is asked to report turning rate and direction. He is then instructed to turn his head in various positions and report his sensations. Finally the chair is decelerated and stopped, and again he reports his sensations. The procedure is designed to create disorientation in the pilot. Pilots almost invariably report changes in speed, direction, and attitude which they sense when the movement is actually a constant velocity, turning in a clockwise direction.

12. Dean, P. J. The human factor in cyclic aircraft accident patterns. In K.G.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

Investigations were directed toward (a) identifying and describing any cyclic yearly patterns in the accident rates of the CF-104 flying with the Canadian Forces Europe, (b) isolating the human factors that produce such patterns, and (c) translating the findings into recommendations that can be used to prevent aircraft accidents. A preliminary analysis of accident rates in the CF-104 has indicated that accidents tend to occur more frequently in January, April, July, and October than in other months. The paper presents the initial analyses and discusses the proposed investigations of this pattern, particularly time-series analyses. The paper also discusses cyclic human factors that the author suspected were operating in these months and the current investigations into changes in life events of the pilots.

13. Demaio, J., et al. Visual scanning: Comparisons between student and institute pilots. Brooks AFB, Texas: Headquarters, Air Force Human Resources Laboratory, AFHRL-TR-76-10, June 1976.

The performance of instructor pilots was compared with that of student pilots in two visual scanning tasks. In the first task both groups were shown

slides of T-37 instrument displays. Some slides contained a significant deviation from a predetermined straight and level course, and the task was to detect the error as quickly as possible. Instructor pilots detected errors faster and with greater accuracy than student pilots, thus providing evidence for the validity of the procedures employed. However, contrary to the concept of a fixed cross-check, student pilots showed a greater tendency to use a systematic search pattern than did instructor pilots. This result suggests that rather than using a rigid scanning pattern, instructor pilots, by virtue of their additional flight experience, use a flexible scanning strategy which allows them to emphasize important or difficult aspects of the display.

In the second experiment the attention diagnostic method task was employed to determine if the experience in visual scanning obtained in the flight situation would transfer to a novel scanning task. In the first session, instructor pilots, student pilots, and a group of university students showed no differences in response latency. Instructor pilots, however, showed a significant linear decrease in latency over the course of eight sessions, while this trend was absent in the other two groups. This suggests that instructor pilots learn to attend to critical features more efficiently than do individuals with little or no flight experience. The results of the present experiments recommend the use of a variety of scanning tasks in the UPT program to facilitate the more rapid development of adaptive scanning strategies.

14. Demos, D. L., Residual attention as a predictor of pilot performance. *Human Factors* 20(4):435-440 (1978).

Sixteen student pilots performed a task combination designed to measure residual attention. Scores on this combination were correlated with performances on flight checks administered periodically during flight training. The multiple correlation between performances on the flight checks and the task combination increased as the students progressed through flight training. The usefulness of residual attention as a predictor of pilot performance is discussed.

15. Dimitrov, D. Reasons for certain errors in piloting. Wright-Patterson AFB, Ohio: Translation and Foreign Technology Divisions. Document No. FTD-ID(RS) I-1762-76, Feb 1977.

A series of case histories are presented that highlight pilot factors which might have an impact on flight performance. Discipline, fatigue, and incomplete learning are discussed. No data are presented for the reader's inspection or analysis.

16. Directorate of Aerospace Safety. Change pace analysis. Norton AFB, California: Air Force Inspection and Safety Center, Aug 1978.

A series of 59 mishaps were studied as to type of activity at the time the mishap occurred, type of aircraft, second-level cause factors, and unique factors such as mission urgency and stress.

The study concludes that the stability of USAF destroyed-aircraft rates, as determined in 1974-76, is changing. The 1977-78 rates appear to be significant increases. Of the mishaps, 81% occurred during daylight hours and 43%

were involved in special missions. Additional analyses highlight the relative contributions of experience, training, overcommitment, and distraction.

17. Famiglietti, L. Quinine water, bad for pilots? Air Force Times, Sep 1979.

This article discusses Armed Forces Institute of Pathology (AFIP) findings that quinine contained in "mixers" may produce spatial disorientation and contribute to aircraft mishaps. The general disruption of inner-ear functions is addressed and a forthcoming AFIP study is cited.

18. Flackenberg, B. Pilot factor in aircraft accident of the German Federal Armed Forces. In K.G.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

An analysis was made with reference to the most frequent types of pilot error in 154 aircraft accidents which occurred in the years 1967-70. Of special interest were differences between pilots of jet aircraft, propeller aircraft, and helicopters. The flying experience of the pilot, his age, and other time-variable factors were also taken into consideration.

In general, errors predominantly occurred during low-level flight and during the leading phase immediately before touchdown. In jet aircraft accidents, most errors were committed by the pilot due to an extreme workload in handling his aircraft. In other categories, particularly propeller-driven aircraft, the more pronounced types of errors were those that may be attributed to the pilot's personal attitude (in extreme cases, resulting in violations). Other authors' findings related to flying experience were confirmed. The age distribution of pilots differed remarkably from data in other publications.

19. Graham, W. Human factors considerations in pilot warning instrument systems. Washington, D.C.: FAA Systems Research and Development Service. Report No. FAA-RD-71-114, Dec 1971.

A pilot warning instrument (PWI) alerts the pilot to the presence of potentially threatening aircraft and thereby increases the probability of detection. Every time a PWI alarms, the pilot can compare the position of aircraft seen, if any, with the information given by the PWI. Whenever another aircraft is seen, the pilot can consider whether or not the PWI has signalled its presence. These experiences will condition the pilot to attach more or less urgency to PWI alarms, and the degree of urgency will directly affect the utility of the PWI. Some rate of alarms on undetected targets will cause the pilot to ignore or turn off the equipment. The question of the relationship between the nature of alarms and pilot performance is quantitative; a simulator capable of reproducing the same stimulus conditions is essential for comparison of various PWI systems. A simulator capable of generating realistic stimuli is essential to obtain quantitatively meaningful results. This report summarizes the aspects of pilot behavior related to PWI operation that require study, outlines a model for generation of appropriate threat environments, and describes a simulator facility designed specifically to study the human-factor considerations in PWI design.

20. Gunning, P. Time estimation as a technique to measure workload. Human Factors Conference Proceedings 22nd Annual Meeting. Santa Monica, California: The Human Factors Society, Inc., 1978.

Based on S. Hart's (NASA Research Center) findings, a secondary task involving time estimation was used as a measure of workload on a flight simulation study. The results of the time estimation task were compared with performance scores for two pilot transport craft and subjective workload ratings to evaluate the adequacy of the task. The successes and failures of the technique are discussed.

21. Hartman, B. O., et al. Fatigue in FB-111 crewmembers. Aerospace Medicine 45(9):1026-1029 (1974).

Fifteen biomedically dedicated missions of 8-hour duration were flown in the FB-111 as part of its initial operational evaluation. Each two-man crew provided data on subjective fatigue, discomfort, efficiency, and pre- and post-mission sleep. In addition, urine samples obtained from one crew on an unusually demanding mission, were analyzed for epinephrine, norepinephrine, 17-hydroxycorticosteroids, sodium, potassium, and urea. The data showed that the crews experienced moderate fatigue and stress, aggravated by physical discomfort, from which they recovered after one night of sleep.

22. Hasbrook, A. H., et al. Performance and heart rate during in-flight USC of a compact instrument display. Washington, D.C.: FAA Office of Aviation Medicine. Report No. FAA-AM-75-12, Nov 1975.

Instrument panels in any general aviation aircraft are becoming increasingly crowded, presenting the pilot with an instrument scanning problem. Because most aircraft instruments require use of central (foveal) vision, the pilot must look directly at each instrument to obtain needed information, taking time that may not be available during an instrument approach to published minimums. To see if problems of adequate scanning might be alleviated by reducing and changing the size of certain instruments and utilizing the pilot's peripheral vision, an in-flight study of pilot performance was conducted with an experimental instrument display. The display was used in flight by low-time and high-time professional pilots. The major findings of this study indicate that pilot performance with the high-contrast instrument display, which employs a vertical and horizontal format and occupies substantially less space than conventional instruments, is equal to pilot performance with conventional instruments, in spite of little familiarization time and without regard to pilot experience. No difference in stress (as measured by heart rate) was evident between the experimental and conventional displays. The pilot's subjective reaction to the new type display was favorable. Panel space requirements can be reduced at least 25% by using the design concepts outlined in this study.

23. Hoffman, W. C., and W. M. Hollister. General aviation pilot stall-awareness training study. Washington, D.C.: FAA Systems Research and Development Service, Report No. FAA-RD-77-26, Sep 1976.

Stall/spin accidents involving general aviation aircraft account for a large number of fatal and serious injuries. In an effort to reduce this accident rate, focus is placed on the potential of enhanced pilot training in the areas of stall/spin recognition, avoidance, and recovery.

The objectives of this study were to determine the weaknesses of present flight training syllabi, the methods of training used, and the flight instruction presently provided in the stall/spin area; to conceive an experimental stall/spin increment to an established flight and ground training syllabus; and to conduct flight and ground test evaluations of this syllabus change and the flight instruction techniques required.

Volunteer student pilots were divided into four groups for the evaluation procedures: Group 1 was the control group and received no additional stall/spin instruction; Group 2 received additional ground instruction in stalls/spins; Group 3 received 2 hours of flight instruction on stall and spin avoidance in addition to the ground school increment; Group 4 was given the same instruction as Group 3 plus training in intentional spins. Evaluation flight tests were conducted prior to and after the training period.

Results indicate that additional ground training in the subject of stall and spins, additional flight training on stall awareness, and/or intentional spin training would all have a positive influence on reducing inadvertent stalls and spins.

24. Hopkins, E. G. How much should you pay for that box? Human Factors 17(5):553-541 (1975).

Some claimed cost, safety, efficiency, and effectiveness advantages of aircraft simulators for training are equivocal. Effectiveness of simulator training depends mostly upon the training procedures. Other factors alleged to influence the effectiveness of simulators vary in their demonstrated importance. These are considered in the contexts of physical simulation vs. psychological simulation, simulation fidelity and motivation, and pilot acceptance. One of the more costly areas of engineering development to increase fidelity of physical simulation is motion systems. No experimental evidence is available to show that simulator motion enhances transfer of training. Cost effectiveness has not been demonstrated for many interesting and attractive features that are standard trimmings on flight training simulators. The acquisition of simulators costing several times as much to own and operate as their counterpart airplanes may produce a backlash that will set back the desirable use of cost-effective simulators in reasonable research and training programs.

25. Israel, D. R., et al. Rationale for improving the protection against midair collision. Washington, D.C.: FAA Associate Administrator for Engineering and Development, Report No. FAA-ED-75-1, Vol. 1, Dec 1975.

This document summarizes the findings, conclusions, and recommendations of a Federal Aviation Administration working group established under the auspices of the Associate Administrator for Engineering and Development to consider the pertinent data, analyses, tests, and other factors bearing on possible methods and techniques for preventing midair collisions. Mandatory

airborne collision-avoidance equipment has no apparent benefit for much of the fleet. Supporting details and information developed by the working group are available in the form of a large number of self-explanatory briefing charts and tables which are contained in Volume II. Source documentation is listed in the bibliography.

26. Kelly, M., et al. Air combat maneuvering performance measurements. Human Factors Conference Proceedings 23rd Annual Meeting, pp. 324-328. Santa Monica, California: The Human Factors Society, Inc., 1979.

Due to the complex, dynamic, and fast-moving nature of the air combat task, performance assessment during air-to-air combat provides many unique measurement problems. A combined analytical and empirical technical approach was used to develop a candidate measurement structure and algorithm for measuring pilot performance during one-versus-one combat maneuvering. Thirty pilots and 405 air engagements were considered in the analysis.

Nearly all 28 candidate measures were found to discriminate between high- and low-skilled pilots during free engagements on the simulator for air-to-air combat. Discriminant analyses provided a measurement algorithm consisting of 13 measures that accounted for 51% of the variance in the performance data and which predicted membership in high- or low-skill groups with 92% accuracy.

27. King, N. W., and E. E. Eddowes. Similarities and differences among superior, marginal, and eliminated undergraduate pilot training. Williams AFB, Arizona: Air Force Human Resources Laboratory. Technical Report No. AFHRL-76-12, May 1976.

A recent study of attrition of students from undergraduate pilot training (UPT) revealed a number of problems with UPT as perceived by the eliminees. That study, however, could not determine whether the problems were specific to eliminees or whether they were indications of general problems for all students in UPT. This study gathered data about training problems from students about to graduate from UPT. Comparisons of information from the graduates with information from the eliminees permitted conclusions to be drawn as to problems general to UPT students as opposed to those specific to students eliminated from the program.

28. Kirkham, W. R., et al. Spatial disorientation in general aviation accidents. Oklahoma City, Oklahoma: Federal Aviation Administration. Technical Report No. FAA AM-78-13, Mar 1978.

Accident reports made by the National Transportation Safety Board for a recent 6-year period were reviewed. Statistical computations were made relating spatial disorientation (SD) to fatal accidents. SD was involved in 2.5% of all general aviation accidents, nonfatal and fatal. However, SD ranked as the third highest cause in fatal small fixed-winged aircraft accidents and was closely related to the second highest cause, continued VFR flight into adverse weather. SD was a cause or factor in 16% of all fatal accidents. When SD was described as a cause or factor in an accident, 90% of the time that accident involved fatalities. Small fixed-wing aircraft (under 12,500 lb) accounted for 97.3% of all SD accidents.

29. Kowalsky, N. B., et al. An analysis of pilot-error-related aircraft accidents. Washington, D.C.: National Aeronautics and Space Administration. Report No. CR2441. Jun 1974.

A multidisciplinary team approach to pilot-error-related U.S. air carrier jet aircraft accident investigation records successfully reclaimed hidden human-error information not shown in statistical studies. New analytic techniques were developed and applied to the data to discover and identify multiple elements of commonality and shared characteristics within this group of accidents.

Three techniques of analysis were used: (1) critical-element analysis, which demonstrated the importance of a subjective qualitative approach to raw accident data and surfaced information heretofore unavailable; (2) cluster analysis, which was an exploratory research tool that will lead to increased understanding and improved organization of facts, the discovery of new meaning in large data sets, and the generation of explanatory hypotheses; and (3) pattern recognition, by which accidents can be categorized by pattern conformity after critical-element identification by cluster analysis.

30. Krause, R. L. A psychological approach to aviation safety. Maxwell AFB, Alabama: Air Command and Staff College. Report No. 1350-77, May 1977.

Pilot and supervisory error continue to account for over one-half of the Air Force's aviation accidents. Through a survey of 50 pilots, this study attempts to apply psychological principles to aviation safety, emphasize the salient psychological attributes of the pilot, and provide a behavioral framework within which to motivate the pilot to act safely.

31. Levison, W. H., et al. Modeling the effects of environmental factors on human control and information. Wright-Patterson AFB, Ohio,: Air Force Medical Research Laboratory. AMRL-TR-76-74, Aug 1976.

The optimal-control pilot/vehicle model has been modified to allow a different treatment of motor-related pilot "noise." Specifically, the concept of "pseudo motor noise" has been implemented to provide a model parameter related more directly to uncertainties about the control system as well as uncertainties about the pilot's control input. In addition, noise is injected on control rate as suggested in a previous study.

Application of the revised model does not support the hypothesis that vibration degrades tracking performance by interfering with motor-related feedbacks. A more tenable hypothesis is that vibration introduces unwanted stochastic control inputs that directly perturb the control system.

32. Matheny, W. G. Training research program plans: Advanced simulation in undergraduate pilot training. Brooks AFB, Texas: Air Force Human Resources Laboratory. Technical Report No. ADA-015-486, June 1975.

This study reviewed major training research questions, assessed priorities via Delphi technique, and produced a list of critically needed studies.

Simulators were determined to be a useful adjunct in the study of motion/vision, visual display contact, sequencing of training tasks, cognitive pre-training, individualized instruction, feedback, and instructor training. Methods for measuring the rate of stall of acquisition were also provided.

33. Mowlbray, J. F. Identifying and quantifying the criticality of human-factors deficiencies in naval aircraft cockpits. Naval Post Graduate School, California: Master's thesis, Mar 1977.

Human factors and system safety engineering concepts frequently have not been incorporated in the design of U.S. Navy aircraft cockpits. The relationship of human-factor cockpit deficiencies to pilot error and operator inefficiency is examined, and the need for a comprehensive data base of these deficiencies is demonstrated. A questionnaire was designed and developed to collect the required data from the operators of naval aircraft. Questionnaire results substantiate the validity of the method for gathering human-factor deficiency data. Recommendations are made for expanding data collection to a Navy-wide basis.

34. Mroska, C. A. Fatigue and aircrew management. Maxwell AFB, Alabama: Air Command and Staff College/EDCC. Report No. 1780-77, May 1977.

The author expresses increasing concern over the human factor involved in the C-141 accidents in the Military Airlift Command. In particular, the fatigue factor is analyzed in regard to the crew duty limitations imposed by current regulations. This study incorporates results from available tests and research on fatigue and synthesizes information from dozens of articles written by doctors, crewmen, and safety agencies. The conclusion of this study emphasizes the need to reduce the crew duty-time limits in a noncombat environment.

35. North, R. A., and K. Graffunder. Evaluation of pilot workload metric for simulator VTOL landing tasks. Proceedings of The Human Factors Society 23rd Annual Meeting, pp. 357-361. Santa Monica, California: The Human Factors Society, Inc., 1979.

A methodological approach to measuring workload was investigated for evaluation of new concepts in VTOL aircraft displays. Multivariate discriminant functions were formed from conventional flight performance and/or visual response variables to best detect experimental differences. The flight performance variable discriminant showed maximum differentiation between cross-wind conditions. The visual-response-measure discriminant maximized differences between fixed vs. motion base conditions and experimental displays. Physiological variables were used to predict the discriminant function values for each subject/condition/trial. The weights of the physiological variables in these equations showed agreement with previous studies. High muscle tension, light but irregular breathing patterns, and higher heart rate with low amplitude all produced higher scores on this scale and thus represented higher workload levels.

36. Pierce, B. J., and J. DeMaio. Validation of an in-flight performance methodology, F-Y ground attack training evaluation. Proceedings of The Human Factors Society 23rd Annual Meeting, pp. 320-323. Santa Monica, California: The Human Factors Society, Inc., 1979.

Validity and applicability were assessed for a measurement methodology developed to evaluate airborne performance on conventional weapon delivery maneuvers. The methodology provides an analysis of pilot performance using a stage-by-stage rating technique. Pilots assigned to an F-4 training squadron served as subjects. Instructor pilot ratings of the individual stages of the delivery yielded a reliable indicator of the quality of performance on that pass. The data addressed issues regarding which stages of the maneuver were most difficult, which improved most over training, and to what extent this improvement affected performance on the entire delivery.

37. Price, D. L. The effects of certain gimbal orders on target acquisition and workload. *Human Factors* 17(6):571-76 (1975).

If air-to-ground imaging sensors are mounted to aircraft by different gimbal order systems, the displayed scene will rotate differently even though the flightpaths are identical. Eighteen experienced pilots were tested to investigate the effects of three gimbal orders--roll-pitch, yaw-pitch, and pitch-yaw--on target detection, recognition, and identification performance and also on operator workload. The pitch-yaw gimbal order was associated with the greatest range-to-target scores and the lightest workloads.

38. Read, R. E. Midair collision prevention of VFR low-altitude training routes. Maxwell AFB, Alabama: Air War College. Technical Report No. 181, Apr 1977.

The limitations of see-and-avoid imposed on the pilot are reviewed, and actions are recommended to lessen the effect of these limitations. Some actions are already being pursued, while others require support from the DOD and the FAA for initiation. Recommended actions are listed in order of priority.

1. Reduce the total number of routes by eliminating and further combining routes. This action is considered primary as it can be accomplished by DOD efforts alone and is necessary if the sectional printing program (Action No. 2) is to gain acceptance of the civil aviation community.

2. Initiate the Sectional Aeronautical Chart printing/publicity program. This action is considered the only suitable means available to advertise the locations of the routes to the general aviation pilot in a usable, practical method. It would be number one in priority if reducing the number of routes was not necessary in order to prevent the potential unacceptable clutter from charting all present routes.

3. Equip all aircraft using low-altitude training routes with high-intensity strobe lights. This program should be continued on the schedule recommended by the General Officer Panel with emphasis on these aircraft.

39. Ricketson, D. S., et al. Incidence, cost, and factor analysis of pilot accident errors in U.S. Army aviation. In K.S.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

From 1953 through 1972, pilot error was a consistently large and costly cause of accidents. Past analytic and prevention efforts have not approached pilot-error accidents in the context of malfunctions among the basic man-machine-environment elements. Such an approach was proposed and seeks to identify the common human-error events in pilot-error accidents. A partial test of this approach was made with helicopter and airplane mishap information in its present form. A factor analysis produced nine meaningful and representative factors: disorientation, overconfidence, procedural decisions, crew coordination, experience, precise multiple control, task saturation, attention, and weather. A component score analysis yielded pilot and mishap background information which was helpful in interpreting the factors. An experimental human-error-events reporting form was developed which holds promise for clearer identification of mishap-causing system elements and corrective measures required.

40. Robins, J. E., and T. G. Ryan. Evaluation of the role of simulators in training airborne ASN operations? In K.G.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

This study investigated the effectiveness of U.S. Navy device 2F69B, a weapons trainer for the P3A and P3B aircraft. The device provides tactics crews with team training in the detection, tracking, and destruction of modern deep-diving submarines. Careful selection, variation, and control of problem conditions should enable instructors to train the tactics teams to analyze and respond to situations likely to occur during the actual anti-submarine-warfare missions. Study results indicate that learning takes place in the simulator, with positive transfer to the operational environment. However, there is room for improvement and modification of the training curriculum. This study was performed under a U.S. Navy NATEC contract.

41. Rolfe, J. M., and J. W. Chappelow. The application of aircrew opinions on cockpit tasks and equipment to flight safety research. In K.G.G. Corkindale (Ed.). Behavioral aspects of aircraft accidents: NATO AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

Twenty-two pilots who flew LLGA aircraft, 15 crews of two-place (pilot and navigator) LLGA aircraft, and 10 crews of four-place (pilot, co-pilot, navigator, and engineer) aircraft were surveyed on tasks, equipment, and safety.

Opinions of amount of workload during nine phases of flying, the nature of the tasks involved at each phase, and cockpit design were assessed by questionnaires completed by pilots. The premise was that in the flight safety context, the opinions of aircrew on the conditions of their job are particularly relevant to accidents attributed to human error.

42. Sanders, M. G., et al. Personality aspects of pilot-error accident involvement. Washington, D.C.: U.S. Army Medical Research and Development Command. USAARL Report No. 75-1, July 1974.

The consistently high frequency of pilot-error accidents in both military and civilian aviation programs does much to support exploratory research that

might help alleviate the problem. Cattell's Sixteen Personality Factors Questionnaire (16 PF) and a dynamic decision-making task (under risk) were given to 51 Army aviators. Accident files were then examined to classify the aviators as to their prior pilot-error accident involvement. Discriminant analyses revealed that the decision-making task scores were unrelated to the pilot-error accident groupings, while the 16 PF scores were able to correctly classify 86% of the aviators as to whether or not they had been previously listed as a cause factor in a military accident. Dependency, practicality, and forthrightness were listed as contributing variables.

43. Sanders, M. G., et al. A cross-validation study of the personality aspects of involvement in pilot-error accidents. Washington, D.C.: U.S. Army Medical Research and Development Command. USAARL Report No. 75-15, Mar 1975.

Pilot-error accidents have dominated accident statistics consistently from the 1940's to the present. Sixty-six aviators were given the 16 PF in an attempt to cross-validate the findings reported by Sanders et al. in 1974 (Ref. 42). The results indicate that the personality factors did not significantly discriminate between the pilot-error accident groups. The primary personality differences between the present sample and the original sample were due to variations in the pilot-error accident-free groups. The findings indicate that individual differences in personality characteristics of the aviators prevent consistent identification of traits associated with pilot-error groups.

44. Santilli, S. R. Critical interfaces between environment and organism in class A mishaps: A retrospective analysis. Brooks AFB, Texas: USAF School of Aerospace Medicine. SAM-TR-80-3, June 1980.

Aircraft mishap prevention efforts in the past have been extremely successful. Since 1970, however, the mishap rate decrease has leveled off, and most experts agree that it can be further reduced. This study focuses on the human-factor aspects of mishap causation. Human-factor aspects have been prominent causes of mishaps, but have only recently received significant scrutiny. The assumption of this study is that both the environment and the organism bring with them a certain degree of mishap potential which is triggered by the interface of the two. Determining these critical interfaces by retrospective analysis of past mishaps is the method used here; the immediate goal is to define the problem more clearly.

A series of 34 major variables were analyzed, 12 attributable to the environment and 22 attributable to the operators. Special attention was paid to physical, system, and descriptive variables. Recommendations are offered for future efforts to avoid these critical interfaces or to decrease the mishap potential inherent in the environment and the organism.

45. Savage, R., et al. Evaluation of the sensitivity of various measures of operator workload using random digits as a secondary task. Human Factors 20:649-54 (1978).

Problems have been encountered in previous research in developing a secondary task measure of mental workload that is both sensitive and stable.

Ordinarily a single measure of secondary task is analyzed as an indicator of difference in workload. The purpose of the experiment reported here was to determine whether alternate measures taken from a single secondary task might prove more sensitive. Twelve subjects participated in the experiment involving a primary task (meter pointer nulling) and a secondary task (reading random digits aloud). The independent variable (primary task difficulty level) was adjusted by changing the number of meters that had to be monitored (two, three, or four meters). Dependent measures were taken on the (1) number of random digits spoken (usual workload formula), (2) longest interval between spoken responses, (3) longest consecutive string of spoken digits, and (4) the number of "triplets" spoken. Results show that dependent measures (1), (3), and (4) were significant, with (1) being the most sensitive.

46. Schiflett, S. G. Voice stress analysis as a measure of operator workload. Proceedings of The Human Factors Society 23rd Meeting, p. 573. Santa Monica, California: The Human Factors Society, Inc., 1979.

This study attempted to determine if frequency modulation changes can be used to detect the amount of situational stress in the voice while subjects performed a four-choice information-reprocessing task at different presentation rates.

A response analysis tester (RATER) presented a four-choice discrimination task in which the subject was required to match a response key to each of four stimuli (numbers 1, 2, 3, and 4) appearing in a display window. The sequence of stimuli was randomly presented in an automatic-paced mode for nine 1-minute tests. The stimuli presentation rates were set at one symbol per 1.5 seconds, 0.75 second, and 0.50 second.

The voice was analyzed by a device called a psychological stress evaluator (PSE), manufactured by Dektor, Incorporated, and developed specifically as a deception-detection instrument. Voice signals were initially recorded on magnetic tape, then processed through filtering circuits and displayed on a strip chart for subsequent visual analysis and interpretation. The coded charts were subjectively scored without any knowledge of conditions by two interpreters trained to recognize stress patterns in speech. The subjective scoring criteria were translated into electronic equivalents and automated on a Varian 73 computer for voice pattern recognition analysis. A comparison of scores from the subjective versus the automated outputs was analyzed for extent of concordance.

47. Schwank, J. C., et al. Pilot performance during flight simulation with peripherally presented visual signs. Proceedings of The Human Factors Society Annual 23rd Meeting. Santa Monica, California: The Human Factors Society, Inc., 1979.

The increasing complexity of modern aircraft systems places a substantial information-processing load on the pilot. This complexity has created a need for alternative methods of nonobtrusive instrument displays. Recent studies indicate dual, independent systems for focal and peripheral vision. In view of nonconscious processing by the far periphery, it follows that the far-peripheral visual field would be a possible location for alternate instrument displays.

This report is a culmination of two experiments, involving 46 male pilot trainees, that investigated the effectiveness of three types of instrument displays during flight in a GA1-1 simulator. Both experiments showed no decrement in pilot performance during a complex instrument maneuver involving normal and peripheral displays. Subjects were less prone to deviate from a given compass heading using the peripheral display (PEF.001). A secondary task (digit canceling) used to simulate secondary tasks involved in actual flight also did not diminish performance across displays. These results are consistent with a dual theory of visual processing and the notion of nonobstrusive prompting.

48. Shannon, R. B. Application of a performance model to assess aviator critical incidence. Proceedings of the Human Factors Society 22nd Annual Meeting, pp. 144-145. Santa Monica, California: The Human Factors Society, Inc., 1978.

Previous research by the author had developed nine regression equations to assess student aviator performance at various stages of naval air training. The predictor variables were 12 factors based on error behavior in the first stage of training (primary phase). The purpose of the present research was to extend this model by longitudinally assessing 73 pilots into the fleet. Mishap safety records of these pilots were investigated. Of this sample, 20 had had an incident anywhere from 1 month to 6 years after the primary training phase. Discriminate analysis was performed using a two-group separation into critical and noncritical performers. The predictor variables were the same 12 factors and nine stage grades used during model development. A chi-square test was performed on the 2x2 table of predicted-versus-actual critical/noncritical behavior. The value was highly significant ($\chi^2 = 12.0$ $p < .001$) with 53 hits, 26 misses, and a ϕ correlation of .394. A paradoxical trend was indicated by the data: individuals with high grades and low errors were the ones who had the major share of mishaps, while the reverse was true of the noncritical performers.

49. Shannon, R. B., and W. L. Wang. Human factors approach to aircraft accident analysis. In K.G.G. Corkindale (ed.), Behavioral aspects of aircraft accidents: NAFD AGARD Conference Proceedings No. 132. London: Technical Editing and Reproduction Ltd., Dec 1973.

Naval accident reports involving the P-3 and F-4 aircraft were examined over 5- and 7-year periods, respectively. P-3 data from July 1966 to June 1971 and F-4 data from January 1963 to December 1969 were collected from records kept on file with the Naval Safety Center in Norfolk. The critical incident technique was used to catalogue, describe, and analyze operational flightcrew error in both aircraft. The P-3 and F-4 aircraft were selected because of their completely different fleet missions and handling characteristics.

Human errors were categorized by three types: (1) vigilance errors, (2) procedural errors, (3) perceptual motor errors. Phases of flight operation were divided into four segments: (1) servicing preflight/postflight, (2) start/taxi/shutdown, (3) takeoff/landing, (4) inflight. Four remedial areas were outlined for reducing human errors: (1) crew coordination, (2) design, (3) discipline, (4) training.

From the F-4 accident reports, 417 human errors were isolated; and from the P-3 reports, 345 errors. Twenty-eight major error categories emerged from an analysis of these errors. The accident reports were further analyzed for errors that occurred in both aircraft. Twenty common-error groups were found, representing 11.9% and 13.3% of the total errors in the P-3 and the F-4 respectively. Procedural errors and the flight segment of the takeoff/landing shared the most commonality across the two aircraft.

The results of this investigation suggest that although common errors can be isolated across highly dissimilar aircraft with highly different flight missions, they comprise a relatively small percentage of total errors. By far, the majority of errors concern characteristics unique to a particular aircraft. Implications for the remedial areas of crew coordination, training, discipline, and design are discussed.

50. Siegfried, J. G. Psychophysiological effects of aging--developing a functional age index for pilots: II. Taxonomy of psychological factors. Washington, D.C.: Federal Aviation Administration. Technical Report No. FAA AM-78-16, Mar 1978.

One major objective of gerontological aviation psychology is to determine the psychological variables, functions, abilities, skills, and factors that underlie, constitute, or are associated with pilot performance and proficiency. They must be identified, analyzed, and measured if functional age is to substitute for chronological age as a criterion for terminating an aviator's career.

Three methodological approaches used to determine the psychological and psychophysiological factors thought to be representative of and essential to effective pilot performance are (1) analysis of successful pilot behavior as displayed under simulated and operational conditions, (2) analysis of unsuccessful pilot behavior (pilot error) as related to aircraft accidents, and (3) evaluation of pilot performance during the selection and training procedures as reported in the literature. By means of factor analyses, logical deductions, and clinical interpretations of the results obtained by various investigators, 14 factors are identified and described. These are (1) perception, (2) attention, (3) reaction, (4) orientation, (5) sensorimotor, (6) stamina, (7) cognition/mentation, (8) interpersonal relations, (9) decision making, (10) experience, (11) learning, (12) personality, (13) mechanical ability, and (14) motivation.

No attempt is made to assign weights to these factors or to rank them in accordance with their importance to flying proficiency. However, their relationship to age and the aging pilot is discussed.

51. Simpson, T. R., et al. Estimation of UG3RD safety benefits. Washington, D.C.: Office of Aviation Policy. Technical Report No. FAA-AVP-77-8, Jan 1977.

This study estimates the value of aviation safety improvements that could be obtained by implementing various alternative configurations of the Upgraded Third Generation ATC System. Estimates are based on the central assumption that the frequency of aviation accidents per operation observed in the past

will be repeated unless identifiable steps are taken to eliminate specific classes of accidents. Recent accident data on midair collisions and controlled collisions with the terrain were examined to identify types of accidents that could be prevented by the UG3RD. Preventable accident rates were calculated and used to forecast future accidents under an extension of today's system, as well as accidents that could be prevented by the UG3RD.

52. Smith, J. F., and W. G. Matheny. Continuation versus recurrent pilot training. Brooks AFB, Texas: Air Force Human Resources Laboratory. Technical Report No. AFHRL-TR-76-4, May 1976.

This report provides a brief survey of literature on retention of motor, procedural, and communication skills judged relevant to pilot training. Also included are data concerning more recent pilot recurrent training information available from the United States Air Force, the United States Army, and the Federal Aviation Agency. Implications of this data for USAF continuation pilot training are discussed, and an approach to obtaining more specific information is recommended. Some of the findings are as follow:

- Motor skills associated with VFR flight are retained longer and regained much more quickly than instrument or procedural and verbal skills.
- Inactivity for 1 year results in near maximum loss of skills (one estimate is 90%), and subsequent periods of inactivity add little to average upgrade time requirements.
- If instrument flight skills are maintained at a high level, contact flight skills tend to remain at an acceptable level.
- Overlearning promotes improved retention of all categories of skills.

53. Stodola, E. K. Visual collision avoidance in high-speed, low-altitude testing and training operation. Kirtland AFB, New Mexico: Air Force Special Weapons Center Report No. AFSWC-TR-76-1, Apr 1976.

This technical report is directed to the special problem of potential collisions between aircraft of different operating speeds, and examines quantitatively some factors involved in determining both horizontal and vertical evasion maneuvers. Simple criteria are given for assessing collision potential and evasive maneuvers.

A simplified quantitative consideration of collision avoidance by an aircraft substantially faster than the possible-collision-hazard aircraft indicates that judgments of collision potential and avoidance maneuvers can be based on simple viewing angles rather than time-consuming estimates of the rate of movement of the line of sight (relative bearing rate) to the other aircraft. In altitude-change evasion maneuvers, the fast aircraft has much greater potential for climb than does the slow aircraft and, in general, should climb rather than descend.

54. Storm, W. F., et al. Endocrine-metabolic effects in short-duration, high-workload missions: Feasibility study. Brooks AFB, Texas: USAF School of Aerospace Medicine. SAM-TR-76-30, Aug 1976.

A study was conducted at the USAF Instrument Flight Center to test an assembly of measures for assessing the relative merits of various flight-instrumentation systems. The USAF School of Aerospace Medicine (SAM) Stress Battery was included. Eight pilots were provided with three different flight-paths associated with different workloads. Although the study was not designed to permit an optimal evaluation of the SAM Stress Battery, anticipatory stress, mild flight stress, and no habituation across missions were noted. The SAM battery appears to be a useful addition to the flight-instrumentation research program.

55. Storm, W. F., and J. D. Hapenny. Mission crew fatigue during Rivet Joint operations. Brooks AFB, Texas: USAF School of Aerospace Medicine. SAM-TR-76-36, Sep 1976.

Subjective fatigue and sleep data were collected from a USAF Security Service airborne mission team before and during an airborne mission. The primary purpose of the test was to refine the procedures and analytical techniques in preparation for an upcoming demonstration/evaluation of a new and modernized system. Results indicated that only minor changes in procedures and techniques were necessary. The data also provide unique baseline information for future comparison and evaluation of similar data from the modernized system.

56. Williams, R. R. Proposed military characteristics for collision warning device. U.S. Army Aviation Board. Technical Report No. AVN 4356, Feb 1957.

This article describes, in detail, the functional characteristics of a collision warning device. The method of warning and presentation of data along with reliability and operability dimensions are also specified.

57. Williges, R. C., and W. W. Wierwille. Behavioral measures of aircrew mental workload. Human Factors 21(5):129-141 (1979).

Behavioral research literature pertaining to the measurement of aircrew workload was classified into general categories of subjective opinion, spare mental capacity, and primary task metrics. Thirteen specific classes of workload measures related to these general categories were reviewed specifically in regard to aircrew workload assessment in the flight test and evaluation. Each class of measures was summarized in terms of background, applications, and implications for research and implementation. It was concluded that no single measure could be recommended as the definitive behavioral measure of mental workload. Due to the multidimensionality of workload, the most promising assessment procedure apparently should include multiple measures of subjective opinions, spare mental capacity, and primary task measures as well as physiological correlates.

APPENDIX B. EXHIBITS OF INVESTIGATIVE AIDS

EXHIBIT B-1. CODING GUIDE

	<u>Computer card column #</u>
Aircraft type	_____ (1-5)
Date of accident	_____ (6-9)
	Mo. Day Year
Number of fatalities	_____ (10)
Cost of accident	_____ (11-18)
 <u>WEATHER:</u> (Tab C)	
Sky condition	1 - Clear 2 - Obscuration (19) 3 - Cloud cover 4 - Turbulence 9 - N/A
Visibility	_____ (20-22)
	(Code # of miles)
	MD=999
Wind direction	_____ (23-24)
	MD=99
Wind velocity	_____ knots
	MD=999 (25-27)
Temperature	_____ Fahrenheit
	MD=99 (28-30)
Dew point	_____ Fahrenheit
	MD=99 (31-32)
Weather condition	0 - Clear 1 - Fog 2 - Rain 3 - Sleet (33) 4 - Snow 5 - Thunderstorms 6 - Tornadoes 7 - Special warnings 9 - N/A

MECHANICAL/EQUIPMENT: (Tab D)

Aircraft

Total flight hours _____ # hours(34-38)
MD=99999

Hours since last overhaul _____ # hours(39-42)
MD=9999

Flight hours since last overhaul _____ # hours(43-46)
MD=9999

Engine:

Total flight hours _____ # hours(47-51)
MD=99999

Hours since last overhaul _____ # hours(52-54)
MD=999

Flight Controls/Instruments: (Tab I and S)

Flight Controls 0 - Operating (55)
1 - Defective
9 - N/A

ELECTRICAL/MECHANICAL: (Tabs I and S)

Electrical system 0 - Operating (56)
1 - Defective
9 - N/A

Hydraulic system 0 - Operating (57)
1 - Defective
9 - N/A

Radio 0 - Operating (58)
1 - Defective
9 - N/A

Engine 0 - Operating (59)
1 - Defective
9 - N/A

HUMAN FACTORS: (Tab X)

Pilot age	_____ years (60-61)
	MD = 99
Days since last flight	_____ # days (62-65)
	MD = 9999
Hours flown previous 24 hours	_____ # hours (66-67)
	MD = 99
Hours flown previous 48 hours	_____ # hours (68-69)
	MD = 99
Number of sorties flown previous 24 hours	_____ # sorties (70)
	MD = 9
ID Number	_____ 1 (71-74)
Number of sorties flown previous 48 hours	_____ # sorties (75)
	MD = 9
Total number of sorties flown this aircraft	_____ # sorties (76-78)
	MD = 999
Hours worked previous 24 hours	_____ # hours (1-2)
	99 = MD
Hours worked previous 48 hours	_____ # hours (3-4)
	99 = MD
Hours slept previous 24 hours	_____ # hours (5-6)
	99 = MD
Hours slept previous 48 hours	_____ # hours (7-8)
	99 = MD
Hours continuous duty prior to mishap	_____ # hours (9-10)
	99 = MD
Time in cockpit prior to flight	_____ # minutes (11-13)
	999 = MD
Number of days since last flight (this model)	_____ # days (14-16)
Flying hours (total)	_____ # hours (17-21)
	99999 = MD

Note: The next eleven items refer to the coder's own interpretation of the accident. If you feel a factor occurred during the flight, mark it down. You do not have to rely on the opinion of the Investigation Board.

Channelized attention	0 - No 1 - Yes 9 - N/A	(47)
Vertigo/Disorientation	0 - No 1 - Yes 9 - N/A	(48)
Distraction	0 - No 1 - Yes 9 - N/A	(49)
Location of distraction	0 - In cockpit 1 - Outside cockpit 9 - N/A	(50)
Panic	0 - No 1 - Yes 9 - N/A	(51)
Alcohol/Drugs 12 hours prior to mishap	0 - No 1 - Yes 9 - N/A	(52)
Work load too heavy	0 - No 1 - Yes 9 - MD	(53)
Preexisting pilot illness	0 - No 1 - Yes 9 - MD	(54)
Stress	0 - No 1 - Yes 9 - MD	(55)
Overconfidence	0 - No 1 - Yes 9 - MD	(56)
Excessive motivation to succeed	0 - No 1 - Yes 9 - MD	(57)

Pilot's physical condition	1 - Good (58) 2 - Fair 3 - Poor 9 - MD
Length of flight	_____ # hours(59-60)
<u>SITUATION: (Tab C)</u>	
Altitude when mishap sequence began	_____ # Feet(61-65) 99999 = MD
Time of day	1 - Dusk (66) 2 - Dawn 3 - Day 4 - Night
Phase of flight (Tab 5)	1 - Takeoff (67) 2 - Climbout 3 - Enroute 4 - Range 5 - Descent 6 - Landing 9 - N/A
Mission element	1 - Air-to-ground ordinance delivery (68) 2 - Low-level navigation (below 5000 ft.) 3 - Low-level maneuvering (below 5000 ft.) 4 - Air-to-air engagement 5 - Rejoin formation 6 - Maneuver with formation 7 - Search & rescue 8 - Acrobatics
ID number	_____ 2 (71-74)

HUMAN-FACTOR CONCLUSIONS OF INVESTIGATING BOARD

Psychophysiological Factors:

Food poisoning	0 - No	1 - Yes	(1)
Motion sickness	0 - No	1 - Yes	(2)
Other acute illness	0 - No	1 - Yes	(3)
Other preexisting disease/defect	0 - No	1 - Yes	(4)
Get-homeitis	0 - No	1 - Yes	(5)
Hangover	0 - No	1 - Yes	(6)
Sleep deprivation, fatigue	0 - No	1 - Yes	(7)
Fatigue, other	0 - No	1 - Yes	(3)
Missed meals	0 - No	1 - Yes	(9)
Drugs prescribed by medical officer	0 - No	1 - Yes	(10)
Drugs, other	0 - No	1 - Yes	(11)
Alcohol	0 - No	1 - Yes	(12)
Visual illusions	0 - No	1 - Yes	(13)
Unconsciousness	0 - No	1 - Yes	(14)
Disorientation/Vertigo	0 - No	1 - Yes	(15)
Hypoxia	0 - No	1 - Yes	(16)
Hyperventilation	0 - No	1 - Yes	(17)
Dysbarism	0 - No	1 - Yes	(18)
Carbon monoxide poisoning	0 - No	1 - Yes	(19)
Boredom	0 - No	1 - Yes	(20)
Inattention	0 - No	1 - Yes	(21)
Channelized attention	0 - No	1 - Yes	(22)
Distraction	0 - No	1 - Yes	(23)
Preoccupation with personal problems	0 - No	1 - Yes	(24)
Excessive motivation to succeed	0 - No	1 - Yes	(25)
Overconfidence	0 - No	1 - Yes	(26)
Lack of self-confidence	0 - No	1 - Yes	(27)
Lack of confidence in equipment	0 - No	1 - Yes	(28)
Apprehension	0 - No	1 - Yes	(29)
Panic	0 - No	1 - Yes	(30)

Coder's general impression:

Accident sequence initiated by	1 - Human factors	(31)
	2 - Nonhuman factors	
	9 - N/A	
Pneumatic system	0 - Operating	(32)
	1 - Defective	
	9 - MD	

Instrumentation	0 - Operating 1 - Defective 9 - MD	(33)
Navigation system	0 - Operating 1 - Defective 9 - MD	(34)
Other systems	0 - Operating 1 - Defective 9 - MD	(35)
Recently unscheduled maintenance	1 - No 1 - Yes 9 - MD	(36)
Hours flown - this aircraft	<u> # hours</u> 9999 = MD	(37-40)
ID number	<u> </u> 3	(71-74)

EXHIBIT B-2. ABSTRACTING FORM

DOCUMENT REVIEW

HUMAN FACTORS IN AIRCRAFT ACCIDENTS
("TECHNOLOGIES" ARTICLES)

Title:

Author, organization:

Document number:

Date:

Reviewer:

1. Brief description of article

2. Brief description of technology

3. Problems it is used for

4. Method by which it was tested

a. Number of cases: _____

b. Population tested (e.g., Air Force, Army, civilian)

c. Description of testing procedure

5. Results (i.e., Did the technology work? Note how the evaluation of the technology was made.)

6. Cost of implementing the technology (if available)

7. Were other technologies mentioned and evaluated? (If so, describe)

8. Reviewer's perception of the quality of the study and the technology

9. Other studies cited that may be of use

DOCUMENT REVIEW

HUMAN FACTORS IN AIRCRAFT ACCIDENTS
("CAUSES" ARTICLES)

Title:

Author, organization:

Document number:

Date:

Reviewer:

1. Brief description
2. Source of data used
3. Number of cases
4. Types and models of aircraft (rotary/fixed wing, fighter, trainer, transport, large/small passenger, etc.)
5. Effect of the variable under study (including variables, dollar costs associated, strength of relationship, relative importance of variables to other factors).

6. Remedies suggested to overcome problems

7. Evaluation of remedies

8. Reviewer's perception of quality of the study

9. Other studies cited that may be of use

EXHIBIT B-3. MAJOR HUMAN FACTORS INVESTIGATED BY AIR FORCE, ARMY, AND NAVY

FORM OFFICIAL USE ONLY When Filled In

III. PSYCHOPHYSIOLOGICAL AND ENVIRONMENTAL FACTORS																		
INSTRUCTIONS Complete on all occupants of aircraft, all injured persons, and all persons possibly contributing to the cause of the mishap. Supervisory factors attributed to persons not in the aircraft and such factors as design or weather should be reported only for the person in primary control of the aircraft. Factors contributing to injury during mid-air collisions, crash landings, ditchings, etc., are to be considered part of survival phase. Use codes at right to show only those factors present or contributing in each phase.					PHASES OF MISHAP			FACTOR		IMPORTANCE								
					1	ACCIDENT	1	DEFINITE										
					2	ESCAPE	2	CONTRIBUTORY										
					3	LANDING	3	SUSPECTIVE FACTOR										
					4	SURVIVAL (includes precrash landings)	4	CONDITION PRESENT BUT DID NOT CONTRIBUTE TO ACCIDENT OR INJURY										
					5	RESCUE												
FACTORS					A	E	L	S	R	FACTORS	A	E	L	S	R			
1 SUPERVISORY FACTORS										VISUAL ILLUSIONS						613		
INADEQUATE BRIEFING 101										UNCONSCIOUSNESS						614		
ORDERED/LED ON FLIGHT BEYOND CAPABILITY 102										DISORIENTATION/VERTIGO						615		
POOR CREW COORDINATION 103										HYPOXIA						616		
OTHER (Specify) 199										HYPERVENTILATION						617		
2 PRE-FLIGHT FACTORS										DYSBARISM						618		
FAULTY FLIGHT PLAN 201										CARBON MONOXIDE POISONING						619		
FAULTY PRE-FLIGHT OF AIRCRAFT 202										BOREDOM						620		
FAULTY PREPARATION OF PERSONAL EQUIP 203										INATTENTION						621		
HURRIED DEPARTURE 204										CHANNELIZED ATTENTION						622		
DELAYED DEPARTURE 205										DISTRACTION						623		
INADEQUATE WEATHER ANALYSIS 206										PREOCCUPATION WITH PERSONAL PROBLEMS						624		
OTHER (Specify) 299										EXCESSIVE MOTIVATION TO SUCCEED						625		
3 EXPERIENCE/TRAINING FACTORS										OVERCONFIDENCE						626		
INADEQUATE TRAINING 301										LACK OF SELF-CONFIDENCE						627		
LIMITED TOTAL EXPERIENCE 302										LACK OF CONFIDENCE IN EQUIPMENT						628		
LIMITED RECENT EXPERIENCE 303										APPREHENSION						629		
FAILURE TO USE ACCEPTED PROCEDURES 304										PARIC						630		
OTHER (Specify) 399										OTHER (Specify)						699		
4 DESIGN FACTORS										7 ENVIRONMENTAL FACTORS								
DESIGN OF INSTRUMENTS, CONTROLS 401										ACCELERATION FORCES, IN-FLIGHT							701	
LOCATION OF INSTRUMENTS, CONTROLS 402										ACCELERATION FORCES, IMPACT							702	
FAILURE OF INSTRUMENTS, CONTROLS 403										DECOMPRESSION							703	
COCKPIT LIGHTING 404										VIBRATION							704	
RUNWAY LIGHTING 405										GLARE							705	
LIGHTING OF OTHER AIRCRAFT 406										SMOKE, FUMES, ETC							706	
PERSONAL EQUIPMENT INTERFERENCE 407										HEAT							707	
WORKSPACE INCOMPATIBLE WITH MAN 408										COLD							708	
OTHER (Specify) 499										WIND BLAST							709	
5 COMMUNICATIONS PROBLEMS										VIS. RESTR - WEATHER HAZE DARKNESS							710	
MISINTERPRETED COMMUNICATIONS 501										VIS. RESTR - ICING, WINDOWS FOGGED, ETC							711	
DISRUPTED COMMUNICATIONS 502										VIS. RESTR - DUST, SMOKE, ETC., IN ACFT							712	
LANGUAGE BARRIER 503										WEATHER, OTHER THAN VISIBILITY RESTR							713	
NOISE INTERFERENCE 504										OTHER (Specify)							799	
OTHER (Specify) 599										8. OTHER FACTORS TO BE CONSIDERED								
6 PSYCHOPHYSIOLOGICAL FACTORS										HABIT INTERFER., USED WRONG CONTROL							801	
FOOD POISONING 601										CONFUSION OF CONTROLS, OTHER							802	
MOTION SICKNESS 602										MISREAD INSTRUMENTS!							803	
OTHER ACUTE ILLNESS 603										MISINTERPRETED INSTRUMENT READING								804
OTHER PRE-EXISTING DISEASE/DEFECT 604										MISLED BY FAULTY INSTRUMENT								805
GET-HOME-ITIS 605										VISUAL RESTR. BY EQUIP. STRUCTURES								806
HANGOVER 606										TASK OVERSATURATION								807
SLEEP DEPRIVATION FATIGUE 607										INADEQUATE COORDINATION OR TIMING								808
FAT/GUE OTHER 608										MISJUDGED SPEED OR DISTANCE								809
MISSED MEALS 609										SELECTED WRONG COURSE OF ACTION								810
DRUGS PRESCRIBED BY MEDICAL OFFICER 610										DELAY IN TAKING NECESSARY ACTION								811
DRUGS OTHER 611										VIOLATION OF FLIGHT DISCIPLINE								812
ALCOHOL 612										NAVIGATIONAL ERROR								813
NAME OF INDIVIDUAL										NAVDERTENT OPER SELF-INDUCED								814
										NAVDERTENT OPER MECHANICALLY INDUCED								815
										OTHER (Specify)								899

FOR OFFICIAL USE ONLY When filled in:

IV. PERSONAL DATA											
1. ROLE OF THIS INDIVIDUAL IN THE CAUSE OF THIS ACCIDENT											
A. PRIMARY						B. CONTRIBUTING			C. NONE		
1. DEF.	2. PROB.	3. POSS.	4. DEF.	5. PROB.	6. POSS.						
C. DUTY OR ROLE AT TIME OF ACCIDENT											
2. BACKGROUND DATA (Complete for all pilots and others who possibly contributed to mishap)											
A. DATE LAST LEAVE ENDED (Day-Mo.-Yr.)		B. DAYS DURATION LAST LEAVE		C. TYPE OF LAST LEAVE TAKEN							
				1. ORD.	2. EMERG.	3. REENLIST	4. GRADUATION	5. SICK OR CONVALESCENT	6. DELAY ENR.	7. UNKNOWN	
D. DATE OF LAST PREVIOUS FLIGHT (Day-Mo.-Yr.)		E. HOURS FLOWN IN LAST 24 HOURS		F. HOURS FLOWN IN LAST 48 HOURS		G. SORTIES FLOWN IN LAST 24 HOURS					
H. SORTIES FLOWN IN LAST 48 HOURS		I. HOURS WORKED IN LAST 24 HOURS		J. HOURS WORKED IN LAST 48 HOURS		K. HOURS SLEPT IN LAST 24 HOURS					
L. HOURS SLEPT IN LAST 48 HOURS		M. HOURS CONTINUOUS DUTY PRIOR TO MISHAP		N. HRS. CONTINUOUSLY AWAKE PRIOR TO MISHAP		O. HOURS DURATION OF LAST SLEEP PERIOD		P. TIME IN COCKPIT PRIOR TO FLIGHT (Hrs., Min.)			
Q. DATE LAST PREVIOUS FLT. THIS MODEL		R. DURATION PREVIOUS FLT. THIS MODEL		S. DATE DEPLOYED				T. NO. DAYS IN AREA		U. TIME SINCE DEPLOYMENT	
3. PHYSIOLOGICAL AND VERTIGO TRAINING (For all personnel)											
V. TYPE OF TRAINING ACCOMPLISHED						W. PLACE TRAINING ACCOMPLISHED				X. COMPLETED	
										MONTH	YEAR
										Y. ROLE IN MISHAP	
4. ANTHROPOMETRIC DATA											
A. DATE OF BIRTH (Day-Month-Year)				D. SITTING HEIGHT (Inches)				G. BUTTOCK-KNEE LENGTH (Inches)			
B. HEIGHT (Inches)				E. TRUNK HEIGHT (Inches)				H. LEG LENGTH (Inches)			
C. WEIGHT (Lbs.)				F. FUNCTIONAL REACH (Inches)				I. SHOULDER WIDTH (BIDELTÖID) (Inches)			
J. TOTAL YEARS OF FORMAL EDUCATION				K. GRADUATION FROM UNDERGRADUATE FLIGHT TRAINING							
				L. BASE				M. DATE			
5. AVIATION SCHOOLS ATTENDED SINCE GRADUATION (Include date of completion)											
6. FLYING EXPERIENCE (Attach copy of individual flying experience as outlined by AFR 127-2)											
A. TOTAL FLYING HOURS (Including AP time, student and other accredited time)						C. TOTAL TIME THIS AIRCRAFT					
B. TOTAL JET TIME						D. TOTAL WEATHER INSTRUMENT HOURS					
FIRST PILOT AND INSTRUCTOR PILOT HRS.		30 DAYS		60 DAYS		90 DAYS		TOTAL			
ALL AIRCRAFT		E.		H.		K.		N.			
THIS AIRCRAFT		F.		I.		L.		O.			
SORTIES THIS AIRCRAFT		G.		J.		M.		P.			
Q. ORIGINAL AERONAUTICAL RATING AND DATE		R. PRESENT AERONAUTICAL RATING AND DATE		S. DATE OF LAST CHECK				T. AFSC			
				U. INSTRUMENT		V. PROFICIENCY		W. PRIMARY DUTY			
7. AVIATION SERVICE CODE AND FLYING ACTIVITY CATEGORY (A-1, H-1, ETC.)											
CURRENT			FROM								
PREVIOUS			TO								
PREVIOUS			TO								
PREVIOUS			TO								
NAME OF INDIVIDUAL			SSAN								
1. For use in mishap form, the following codes will be used: 1. No importance 2. Training definitely helped 3. Training possibly helped 4. Lack of training possible factor 5. Lack of training definitely factor 6. Unknown											

EXHIBIT B-4. PERSONAL DATA RECORDED (AF Form 711GA)

INSTRUCTIONS FOR CODING PAGE 4. PERSONAL SURVIVAL AND ESCAPE EQUIPMENT

The "Required" and "Available" blocks should be answered with an X for "Yes" and left blank for "No". "Required" refers to USAF major air command or base directed requirement. "Available" refers to the items present in the aircraft.

The "Used," "Needed," "Discarded," "Lost," and "Failed" columns are to be marked with an A, E, L, S, R, or combination of these letters to indicate the phase of the mishap when the items lost, are used, etc. (A refers to the accident phase; E to the escape; L to landing; S to survival and R to rescue.)

The last column "Problems" is to be completed by inserting numbers from the following list that correspond to the problems encountered.

- | | |
|--|--|
| <ul style="list-style-type: none"> 01. NOT AVAILABLE - SUPPLY PROBLEM 02. NOT AVAILABLE - LEFT BEHIND 03. DISCARDED 04. LOST 05. DAMAGED - MINOR 06. DAMAGED - MAJOR 07. BURNED - MINOR 08. BURNED - MAJOR 09. DESTROYED BY EXTREME FORCE/FIRE 10. FAILED TO OPERATE (RADIO, ACTUATOR, ETC.) 11. OPERATED PARTIALLY 12. DIFFICULTY LOCATING 13. BEYOND REACH 14. CONNECTION/CLOSURE DIFFICULTY 15. CONNECTION/CLOSURE FAILURE 16. RELEASE/DISCONNECT DIFFICULTY 17. RELEASE/DISCONNECT FAILURE 18. INADVERTENT RELEASE/DISCONNECT 19. INADVERTENT ACTUATION 20. ACTUATION DIFFICULTY 21. ACTUATION FAILURE 22. ACTUATED BY OTHER PERSON 23. RESTRAINT/ATTACHMENT INADEQUACY/FAILURE 24. RESTRAINTS/ATTACHMENTS NOT USED PROPERLY FOR MAXIMUM PROTECTION 25. IMPROPER USE (OTHER) 26. UNFAMILIAR WITH USE 27. COLD HAMPERED USE 28. INJURY HAMPERED USE 29. WATER HAMPERED USE 30. OTHER EQUIPMENT INTERFERED | <ul style="list-style-type: none"> 31. DONNING/REMOVAL PROBLEM 32. DISCOMFORT/BULKINESS 33. POOR FIT 34. LEAKED 35. MATERIEL DEFICIENCY 36. DESIGN DEFICIENCY 37. HANGUP/ENTANGLEMENT (WITH A/C OR OTHER EQUIPMENT) 38. ENTANGLEMENT (PARACHUTE SUSPENSION LINES ONLY) MAJOR 39. ENTANGLEMENT (PARACHUTE SUSPENSION LINES ONLY) MINOR 40. DRAGGING (PARACHUTE ONLY) 41. NON-STANDARD CONFIGURATION 42. AIDED IN LOCATION/RESCUE 43. NOT EFFECTIVE IN LOCATION/RESCUE (USED IN AREA OF SAR VEHICLES) 44. PREVENTED/MINIMIZED INJURY 45. EQUIPMENT PROBLEM (LOSS, FAILURE, ETC.) A FACTOR IN PRODUCING INJURY 46. EQUIPMENT PRODUCED INJURY (HIT BY EJECTION SEAT, ETC.) 47. FAILURE/DELAY IN USING COMPROMISED SURVIVAL/RESCUE 48. ALL CREW EQUIPT (CODE ONCE ONLY) 49. MAINT/INSTALLATION ERROR 50. PROBLEM EXPERIENCED BY OTHERS IN ACTUATION/RELEASE OF EQUIPMENT 51. RIVETS PULLED LOOSE 75. LANDED ON UNDEPLOYED SURVIVAL KIT 88. OTHER |
|--|--|

REVERSE OF PAGE 3

EXHIBIT B-5. HUMAN FACTORS INVESTIGATED BY CANADIAN FORCES

FLYING HISTORY

EMPLOYMENT: STUDENT - 1ST SQUADRON APPT
- LATER SQUADRON APPT
INSTRUCTOR - NONFLYING APPT
- EXTRA QUALIFICATIONS
- INSTRUMENT RATING
DATED

AEROMEDICAL

LAST B2, LAST AMT, LAST EJECTION/SURVIVAL TRAINING

MEDICAL CONDITION

FULL FIT, MEDICAL PROFILE

AWAITING ADMISSION FOR

SUFFERING FROM

CONVALESCENT FROM

MEDICATION IN PREVIOUS 4 WEEKS
NIL, TREATMENT, SELF-MEDICATION

EEG, ECG, HEAD INJURIES

FLYING TIME

TOTAL FLYING TIME

TOTAL TIME ON TYPE

IN LAST 30 DAYS (IF A NIGHT ACCIDENT, INCLUDE TOTAL NIGHT FLYING TIME IN LAST
30 DAYS AND NUMBER OF TAKEOFFS AND LANDINGS)

IN LAST 48 HOURS

IN LAST 24 HOURS

ON DAY OF OCCURRENCE

ASSESSMENTS

PHYSIOLOGICAL STRESS

HYPOXIA
DISORIENTATION
HEAT STRESS
COLD INJURY
INTOXICATION BY CO/OTHERS
DECOMPRESSION SICKNESS
AIR SICKNESS
ACCELERATION
BAROTITIS MEDIA
UPSET OF CIRCADIAN RHYTHM
INCAPACITATION
HYPOGLYCEMIA
HYPERVENTILATION
COMBINED STRESSES: ALCOHOL
 FATIGUE
 NUTRITION
 SELF-MEDICATION

PSYCHOSOCIAL FACTORS

PREVIOUS 30-DAY DUTY/OFF-DUTY HISTORY
PREVIOUS 3-MONTH HISTORY INCLUDING LIFE CHANGE
 (FAMILY, PERSONAL, FINANCIAL, OCCUPATIONAL)
LIFESTYLE (BIOGRAPHY, ACTIVITIES/HABITS, DRIVING)
ATTITUDE AND MOTIVATION
GENERAL INTELLIGENCE, EMOTIONAL STABILITY
PERSONALITY CHARACTERISTICS AND BEHAVIOR

Note: Information of great value has been obtained from sources such as friends, relatives, supervisors, instructors, personal physicians, and other observers who may comment on long-term personal and flying habits, general health, and ordinary behavior of personnel.

NUTRITION

HOURS SINCE LAST FULL MEAL
LAST MEAL WAS
CANTEEN AVAILABLE
IN-FLIGHT FEEDING
ABNORMALITIES OF FEEDING
FLUID INTAKE (STATE OF HYDRATION)

PRESENT POSTING

LENGTH OF TIME AT BASE, ACCOMMODATION, DISTANCE FROM BASE

PERSONAL HISTORY

AGE
MARRIED: WIFE--HEALTH, AGE
 CHILDREN--HEALTH, AGES
SINGLE: GIRL FRIEND, RELATIONSHIPS
ALCOHOL, TOBACCO, HOBBIES, SPORTS
CAR: TYPE, CONDITION OF EXHAUST SYSTEM
FINANCIAL, ECCENTRICITIES, OTHERS
ANTHROPOMETRICS

ACCIDENT HISTORY

AIRCRAFT
MOTOR VEHICLE
OTHER INVOLVING INJURY

FATIGUE

TIME AT CONTROLS THIS FLIGHT
NUMBER OF SORTIES LAST 48 HOURS LAST 7 DAYS
HOURS OF DUTY LAST 48 HOURS
AMOUNT OF SLEEP DAY/NIGHT LAST 24 HOURS
RECENT FATIGUING FACTORS
ACTIVITIES DURING PRLVIOUS 72 HOURS

DATE
ILMED
-8