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THESIS

A HUMAN SYSTEMS INTEGRATION PERSPECTIVE TO EVALUATING NAVAL AVIATION MISHAPS AND DEVELOPING INTERVENTION STRATEGIES

by

Shawn R. Cowan

December 2009

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13. ABSTRACT (maximum 200 words)

This thesis analyzed both the human factors involved in Naval Aviation mishaps and the results of a survey of the safety concerns of Naval aircrews. Naval Aviation mishap data between 2000–2008 revealed skill-based errors and coordination/communication/planning factors to be the leading causes of mishaps. In contrast, the Naval aircrews surveyed in 2008 believed ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) to be the most likely causes of future mishaps. To address these concerns, a mishap intervention generation and evaluation methodology recently created by Shappell and Wiegmann (2006, 2009, in press) called the Human Factors Intervention Matrix (HFIX) was examined. Drawing upon the domains of human systems integration (HSI) and the Joint Capabilities Integration Development System's (JCIDS) doctrine, organization, training, material, leadership, personnel, and facilities (DOTMLPF) analysis, the HFIX methodology was revised and expanded. It is suggested that this revised framework will be useful to both the developers of future Naval aircraft systems and safety professionals in reducing the occurrence of human error-related mishaps.

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This thesis analyzed both the human factors involved in Naval Aviation mishaps and the results of a survey of the safety concerns of Naval aircrews. Naval Aviation mishap data between 2000–2008 revealed skill-based errors and coordination/communication/planning factors to be the leading causes of mishaps. In contrast, the Naval aircrews surveyed in 2008 believed ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) to be the most likely causes of future mishaps. To address these concerns, a mishap intervention generation and evaluation methodology recently created by Shappell and Wiegmann (2006, 2009, in press) called the Human Factors Intervention Matrix (HFIX) was examined. Drawing upon the domains of human systems integration (HSI) and the Joint Capabilities Integration Development System's (JCIDS) doctrine, organization, training, material, leadership, personnel, and facilities (DOTMLPF) analysis, the HFIX methodology was revised and expanded. It is suggested that this revised framework will be useful to both the developers of future Naval aircraft systems and safety professionals in reducing the occurrence of human error-related mishaps.

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LIST OF ACRONYMS AND ABBREVIATIONS

CFIT	Controlled Flight Into Terrain
CFIT-1	Controlled Flight Into Terrain (Enroute Phase)
CFIT-2/ALA	Controlled Flight Into Terrain (Approach and Landing Phase)
CHMSWL	Commander, Helicopter Maritime Strike Wing Atlantic
CHMSWP	Commander, Helicopter Maritime Strike Wing Pacific
CHSCWL	Commander, Helicopter Sea Combat Wing Atlantic
CHSCWP	Commander, Helicopter Sea Combat Wing Pacific
CNAF	Commander, Naval Air Forces
CRM	Crew Resource Management
CSFWL	Commander, Strike Fighter Wing Atlantic
CSFWP	Commander, Strike Fighter Wing Atlantic
DoD	Department of Defense
DoD-HFACS	Department of Defense Human Factors Analysis and Classification System
DOTMLPF	Doctrine, Organization, Training, Material, Leadership, Personnel
FAA	Federal Aviation Administration
FACES	Feasibility Acceptability Cost Effectiveness Sustainability
HFACS	Human Factors Analysis and Classification System
HFIX	Human Factors Intervention Matrix
HSI	Human Systems Integration
JCIDS	Joint Capabilities Integration and Development System

LoC	Loss of Control
Midair	Midair collision
NASA	National Aeronautics and Space Administration
NATOPS	Naval Aviation Training and Operating Procedures Standardization
NTSB	National Transportation Safety Board
R.O.C.	Republic of China
SD	Spatial Disorientation
UAV	Unmanned Aerial Vehicle
USMC	United States Marine Corps
USN	United States Navy

EXECUTIVE SUMMARY

The purpose of this thesis was to determine the leading causes of Naval Aviation mishaps, and develop a methodology for the generation and evaluation of mishap intervention strategies. To this end, three analytical efforts were conducted. The first effort was an analysis of Naval Aviation mishaps to determine the most frequently occurring type of human error. The second effort analyzed the results of a survey of Naval aircrews intended to determine the human errors perceived to be likely causes of future mishaps. The third effort explored and revised a methodology for developing mishap intervention strategies in current and future aircraft systems.

The first analytical effort of this thesis examined Naval Aviation mishap data from FY2000-FY2008. These mishap investigation reports were recently recoded into the Department of Defense Human Factors Analysis and Classification System (DoD-HFACS) taxonomy by a Naval Safety Center analyst. This taxonomy is a standard methodology to classify, catalog, and analyze the contribution of human error to mishaps. For the data available, the most commonly occurring DoD-HFACS categories were determined for the following communities: Navy and Marine Corps combined (F/A-18, AV-8B, H-60, H-53, H-46, UH-1, & AH-1W), overall Navy (F/A-18 & H-60), overall Marine Corps (F/A-18, AV-8B, H-53, H-46, UH-1, & AH-1W), Navy F/A-18, Marine Corps F/A-18, Navy Helicopter (H-60), and Marine Corps Helicopter (H-53, H-46, UH-1, & AH-1W). The top two categories across all communities were skill-based errors and coordination/communication/planning factors. In general, these two categories occurred at a much higher rate than other categories, doubling the occurrence rate of the third place category in many cases. Judgment and decision-making errors appeared in the top five lists of all but Marine Corps helicopters, where it placed seventh. Comparing these results to other aviation mishaps studies that have used HFACS, revealed a degree of commonality in the type of human errors involved in all aviation mishaps (both commercial and military).

The second analytical effort examined the results of a strategic human factors review conducted by the Commander, Naval Air Forces (CNAF) in the spring of 2008. As part of this review, each individual squadron was directed to identify their top five human factors concerns. This data was collected using the nanocodes of the DoD-HFACS classification system. Squadrons were instructed that they could analyze current issues or try to predict the cause of the next mishap. Results from each squadron were compiled at the appropriate type wing (a collection of several squadrons operating similar aircraft platforms) and relayed to CNAF. To allow comparison with the results from the first analytical effort, only F/A-18 and H-60 aircraft data was analyzed. Five out of six type wings for F/A-18 and H-60 squadrons identified ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) as being among their top five concerns. These nanocodes belong to the DoD-HFACS levels of organization, supervision, and preconditions, which sharply contrasted the act-level errors identified in the mishap data from the first analytical effort. While this difference could be influenced by biases inherent in the points of view of mishap investigators and aircrews, it also demonstrates that mishap investigations do not tell the complete story in regards to the causes of mishaps. In order for safety professionals to fully understand all the influential factors causing mishaps, both perspectives must be considered.

The third analytical effort examined a mishap intervention and evaluation methodology, called the Human Factors Intervention Matrix (HFIX), proposed by Shappell and Wiegmann (2006, 2009, in press). A number of recommendations were suggested based upon the unique needs of the Navy to make the framework more useful for program managers involved in the development of new aircraft. HFIX uses five domains of possible intervention sources (organizational/administrative, human/crew, technology/engineering, task/mission, and operational/physical environment) and uses them to guide brainstorming sessions conducted by a group of aviation professionals from varied backgrounds. Once ideas are generated, they are compared and evaluated based of the criteria of feasibility, acceptability, cost, effectiveness, and sustainability. The HFIX domains of possible intervention sources were found lacking and two other sources of intervention strategies were considered: human systems integration (HSI) and doctrine, organization, training, material, leadership, personnel, and facilities (DOTMLPF). Analyzing the merits of each, an alternative list of mishap intervention domains that draws upon the advantages of each was presented. These domains were: mission, manpower, personnel, training, human factors engineering, policy/procedures, leadership, and facilities/environment. Additionally, the original form of HFIX only addresses mishap causes at the acts level of HFACS. Although mishap investigations tend to cite causal errors at this level, the second analytical effort suggests that higher levels such as preconditions, supervision, and organization should also be considered. In the revised version of HFIX, all twenty categories of DoD-HFACS were open to scrutiny.

The cost of mishaps to the Department of Defense in terms of personnel, equipment, and financial resources continues to be a driving factor in the pursuit of reducing aviation mishap rates. Although technological and engineering improvements have drastically reduced the frequency of mishaps over the last 30 years, the remaining constant is human error. It is unlikely human error will ever be eliminated as a mishap casual factor. However, the effective application of the eight mishap intervention domains (mission, manpower, personnel, training, human factors engineering, policy/procedures, leadership, and facilities/ environment) may be able to reduce its influence. The multidisciplinary approach of HSI is useful in comparing the relative merit of various intervention strategies and performing tradeoffs in order to arrive at an acceptable solution. The revised HFIX methodology draws upon this approach to provide a comprehensive approach to mishap intervention.

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I. INTRODUCTION

A. OVERVIEW

On May 19, 2003, Secretary of Defense Donald Rumsfeld issued a memorandum to the secretaries of the armed services challenging them to reduce the number of mishaps and accident rates by at least half within the next two years. Stating that “world class organizations do not tolerate preventable accidents” (Secretary of Defense, 2003, p. 1), Rumsfeld’s directive was aimed at reinvigorating the services’ safety efforts and breaking the stagnation in mishap reduction in recent years. Six years later, the Department of Defense (DoD) has yet to reach its goal, but vigorously continues to pursue it. Besides responsible leadership, simple economics is a large motivator. The cost of preventable accidents to the services consists of both direct and indirect costs. Direct costs include medical treatment, disability payments, and repair or replacement of damaged equipment. Indirect costs are often more difficult to measure, including schedule delays, training replacement personnel, and additional sorties to accomplish the intended mission. With direct costs from mishaps totaling approximately $3 billion annually and indirect costs estimated at approaching four times that amount (Secretary of Defense, 2007), accident reduction efforts potentially represent substantial monetary savings to the U.S. military. In addition to economic costs, mishaps severely affect readiness. The reduction or elimination of preventable accidents would provide a considerable boost to readiness and overall mission effectiveness.

The occurrence of an aircraft mishap usually prompts an investigation to determine the causes. Once causation has been determined, the natural course of action is to develop and implement interventions to prevent a similar mishap from occurring in the future. Traditionally, intervention efforts are focused on the immediate future (e.g., new procedures, additional training, and aircraft modification). There is, however, a broader perspective with which to approach mishap intervention strategies. The mishaps of today can also provide meaningful information towards the prevention of mishaps in the more distant future. Applying the lessons learned from yesterday's mishaps to the design process of tomorrow's aircraft may well prevent future mishaps by avoiding the very conditions and circumstances that make them likely in the first place. For example, a common mishap in retractable landing gear aircraft is to land with the landing gear up simply due to the failure of a distracted pilot to lower them. An aircraft design change that resulted from these mishaps is the gear warning horn, designed to sound when the aircraft is close to the ground and at approach airspeed. In short, to be most effective, safety and mishap prevention should be considered from the outset of system design and not merely once a tragedy has befallen a fielded system.

To break out of what Wiegmann and Shappell (2003) call the "blame and train" paradigm of mishap investigation and intervention, a clear and effective methodology is needed to: a) determine and classify all the relevant causes of mishaps; b) identify the causes most in need of attention; and c) develop effective intervention strategies. Various tools for mishap investigation and classification exist (e.g., Heinrich, Peterson, & Roos, 1980; Reason, 1990; O'Hare, Wiggins, Batt, & Morrison, 1994, Wiegmann & Shappell, 2003). Indeed, organizations such as the National Transportation Safety Board (NTSB), Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and the Naval Safety Center have spent countless man-hours investigating and cataloging the causes of aircraft mishaps. The challenge for safety professionals is to use this data to prevent future accidents. To this end, it is the goal of this thesis to develop a methodology for generating mishap intervention strategies that can be incorporated into the design of future aircraft and aircraft systems.

B. BACKGROUND

Naval Aviation mishaps have been the subject of several studies over the last 50 years (e.g., Borowsky & Wall, 1983; Yacavone, 1993; Shappell & Wiegmann, 1996). The rapid advancement of aviation technology, spurred by several armed conflicts, has demanded that the evolution of management and safety programs keep pace. The fact that Naval Aviation has been more focused on safety than other communities is not surprising. From its very beginning, Naval Aviation has always been an inherently risky enterprise with dire consequences for error. The considerable costs in personnel and equipment provide sizeable incentives to reduce the frequency of mishaps. To illustrate, the 2009 unit cost of an F/A-18E/F is $54.7 million (Department of the Navy, 2009) and a 1999 General Accounting Office report listed the basic cost of training a military pilot at over $1 million (with a cost in excess of $9 million for the pilot to gain full operational experience).

In the early years of Naval Aviation, the mishap rate for class A mishaps, the most serious accident category, enjoyed a dramatically decreasing trend. However, in the last 20 years that decreasing trend has reached a relative plateau (see Figure 1). Naval Aviation owes its significant reduction in mishap rates to both technical and non-technical interventions, including the adoption of angled carrier decks, the establishment of the Naval Safety Center, the implementation of the Naval Aviation Training and Operating Procedures Standardization (NATOPS) program, and others listed in Figure 1. Although the decline in mishap rates seems encouraging, it is important to note that the trend has leveled off. Although some may argue that the current mishap rates may represent the “cost of doing business,” it may instead indicate the last true remaining cause of mishaps—human error.

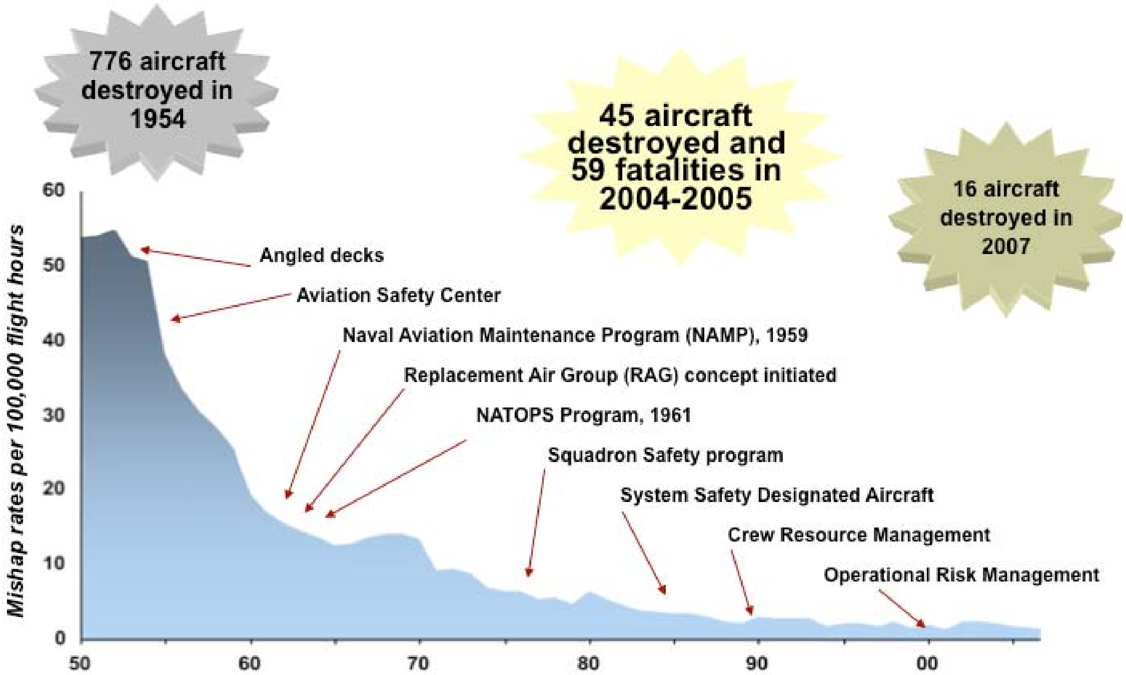

Figure 1. Naval Aviation Safety Historical Perspective (After: Langford, 2009)

The early days of aviation provided ample room for improvement in virtually every aspect of flight safety, from aircraft design, materials, and construction to pilot selection, training, and technique. Over the years, substantial gains have been made in the technical aspects of aviation. Aircraft engines are built to precise standards and operate for thousands of hours without issue. Redundant systems, inherent in today's modern aircraft, provide layers of protection against mechanical component failures. The human element of flight has improved as well, with more rigorous safety procedures, the widespread use of high-fidelity simulator training, and human error avoidance practices, such as crew resource management. However, the reduction of human error in aviation lags behind the decline of mechanical failure.

Shappell and Wiegmann (1996) evaluated 6,700 Naval Aviation mishaps between 1977 and 1992 to determine the proportion of mishaps attributed to human error. Figure 2 illustrates that human and mechanical factors played nearly an equal role in Naval Aviation mishaps in 1977. Although mechanical causes were all but eliminated by 1992, human error had only been reduced by approximately 50%. In more recent data collected by the Naval Safety Center between 2003 and 2007, human error was still found to be responsible, at least in part, for over 90% of Navy and Marine Corps class A flight mishaps (Langford, 2009). Clearly, if further reductions in the mishap rate are to be achieved, eliminating human error must be the focus of safety efforts.

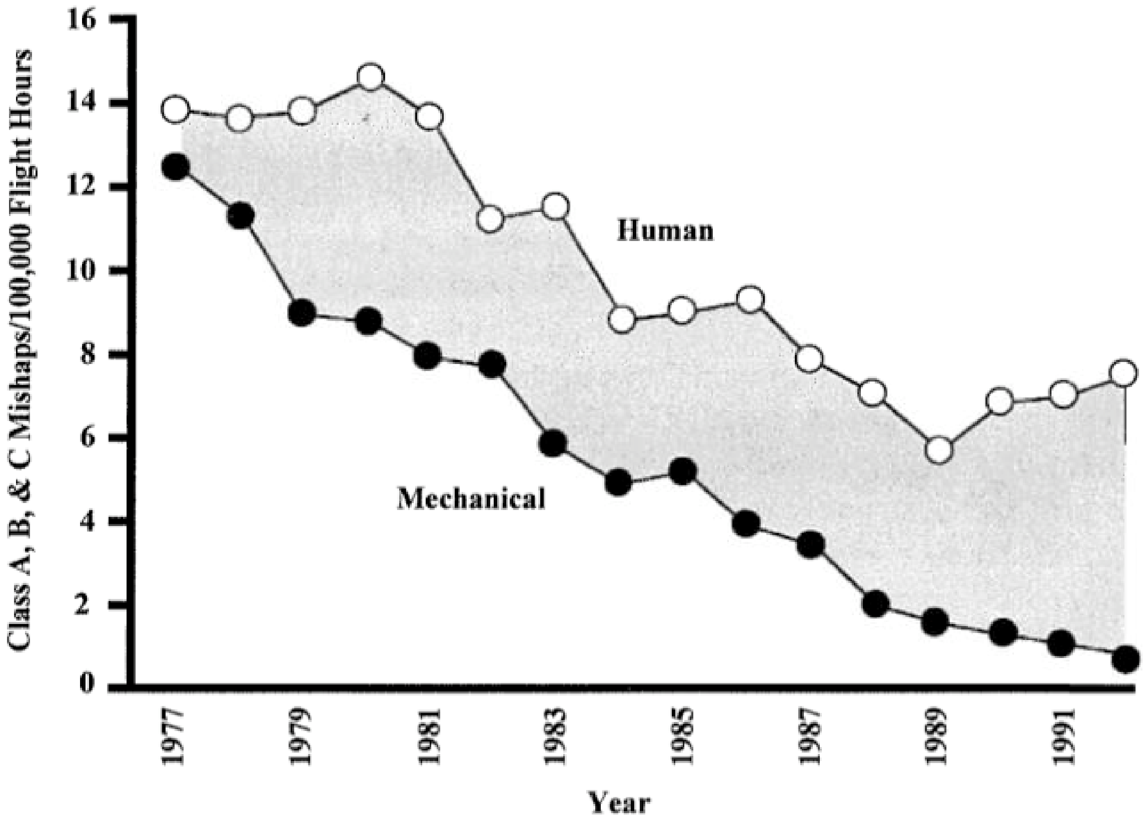

Figure 2. Rate Of Naval Aviation Mishaps Associated With Human Error Versus Those Solely Attributable To Mechanical Or Environmental Factors. (From: Wiegmann & Shappell, 2003, p.11)

Recognizing the considerable role human error plays in today's accidents, Shappell and Wiegmann (1997, 2000, 2001) developed a framework for classifying human factors in mishaps. Their work became the basis for the DoD's Human Factors and Analysis Classification System (DoD-HFACS), which will be discussed in more detail in Chapter II. This taxonomy is the method mandated by the DoD to dissect human error in a systematic way in order to aid mishap investigation, facilitate data collection and storage, and provide quantifiable evidence for the development of mishap prevention strategies. Although DoD-HFACS is useful in its own right for developing interventions, this thesis will draw upon the domains of Human Systems Integration (HSI) as the foundation for incorporating mishap prevention characteristics into the next generation of aircraft.

C. HUMAN SYSTEMS INTEGRATION

Human Systems Integration is an interdisciplinary approach to ensuring the human is thoroughly considered in the design, development, and integration of a new system. The DoD instruction on the operation of the Defense Acquisition System (DoDI 5000.02) requires a system's program manager to have an HSI plan in order to "…optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system" (Undersecretary of Defense for Acquisition, Technology, and Logistics, 2008, p.60). Additionally, DoDI 5000.02 identifies the domains of HSI that must be addressed in the acquisitions process. These HSI domains are:

- Manpower: The number and type of military, DoD civilians, and contractors needed to operate, support, and maintain a system.
- Personnel: The human performance characteristics required of a system's user population to include their knowledge, skills, and abilities.
- Training: The means to enhance and maintain the knowledge, skills, abilities of a system's operators, maintainers, and support personnel to ensure optimal performance.

- Human Factors Engineering: The optimization of human-machine interface in the design and engineering of a system, accounting for the physical, sensory, and cognitive characteristics of the user population.

- Survivability: The capability of a system to evade detection by threats, provide protection, egress and escape for the crew, and avoid fratricide of friendly forces.

- Habitability: The physical environment of the system affecting the morale and quality of life of the user population during sustained operations.

- Safety and Occupational Health: The inherent ability of the system to prevent acute and chronic injury, illness, disability, or death to its operators, maintainers, and support personnel.

This thesis is relevant to five domains of HSI: manpower, personnel, training, human factors engineering, and safety. Manpower, personnel, training, and human factors engineering are the primary domains that can be manipulated during the system acquisitions process in order to produce desired levels of personnel survivability, habitability, safety, and occupational health (Tvaryanas, Brown, & Miller, 2009). Specifically, this thesis will demonstrate a method to generate mishap intervention strategies within these four domains and use an HSI approach to conducting tradeoffs between them.

Intervention strategies may be planned for both the short term, using existing equipment, and the long term, such as next generation systems. The time horizon of the chosen strategy will likely influence the domain of the solution. As an example, mishap interventions in the training domain may lend themselves to responsive solutions that can be executed almost immediately, while manpower, personnel, and human factors engineering interventions may require much longer-term strategies. Whether looking at the next day's operations or the next generation system's design, safety as an HSI domain is produced through the correct balance of manpower, personnel, training, and human factors.

D. RESEARCH OBJECTIVES

The reduction or elimination of human error from the operation of DoD systems would yield a significant savings in money, personnel, and equipment. The DoD-HFACS taxonomy has proven to be a useful tool in determining the human factors causes of mishaps and for highlighting areas of concern for safety experts. HSI has been shown to be a successful approach during the acquisition process in reducing lifecycle costs and maximizing system performance (Booher, 2003). Given the usefulness of these tools to the DoD, the following research objectives were established in order to provide a feedback mechanism between current generation aircraft and future aircraft designers and program managers.

- Identify the human factors causes most often cited in Naval Aviation class A flight mishaps.
- Identify the human factors judged by experts to most likely cause Naval Aviation mishaps in the future.
- Develop a methodology to apply the principles of HSI to mishap intervention strategy development and improve the design of next generation aircraft.

E. THESIS ORGANIZATION

The organization of this thesis departs slightly from the traditional format. In accordance with American Psychological Association standards, a literature review, methods, results, and discussion will be covered. However, the three research objectives enumerated above will each be treated as its own analytical effort. Chapter II provides a comprehensive literature review for all three efforts.

The methods, results, and discussion of each of the three efforts comprise chapters III-V respectively, and chapter VI will contain the thesis' overall conclusions and recommendations.

F. DEFINITIONS

This thesis uses the following definitions taken from the U.S. Navy's OPNAV Instruction 3750.6R, Naval Aviation Safety Program (Chief of Naval Operations, 2007):

Naval Aircraft: Aircraft of the U.S. Navy, U.S. Naval Reserve, U.S. Marine Corps, and U.S. Marine Corps Reserve.

Naval Aviation Mishap: An unplanned event, or series of events, directly involving Naval Aircraft or Unmanned Aerial Vehicles (UAVs) that results in either of the following:

1. Damage in the amount of $20,000 or more to Naval Aircraft or UAVs, other aircraft (DoD or non-DoD), or property (DoD or non-DoD).
2. A reportable injury of bodily harm, such as a cut, fracture, burn, or poisoning received while involved with Naval Aircraft or UAV resulting from a single or one-day exposure to an external force, toxic substance, or physical agent, and result in a fatality, permanent total disability, permanent partial disability, or injuries resulting in the loss of five or more workdays (not including the day of injury).

Flight Mishaps (FM): Those mishaps which result in $20,000 or more damage to a DoD aircraft or UAV or the loss of a DoD aircraft or unmanned aerial vehicle– when intent for flight for DoD aircraft or UAV existed at the time of the mishap.

Naval Aviation Class A Severity Mishap: A Class A mishap is one in which the total cost of damage to property, aircraft, or UAV exceeds $1,000,000, a

Naval Aircraft is destroyed or missing, or any fatality or permanent total disability results from the direct involvement of Naval Aircraft or unmanned aerial vehicle.[1] Loss of a UAV is not a Class A unless the cost is $1,000,000 or greater.

Naval Aviation Class B Severity Mishap: A Class B mishap is one in which the total cost of damage to property, aircraft, or UAV is more than $200,000 but less than $1,000,000, or a permanent partial disability or the hospitalization of three or more personnel results.

Naval Aviation Class C Severity Mishap: A Class C mishap is one in which the total cost of damage to property, aircraft, or UAV is $20,000 or more, but less than $200,000, or results in an injury requiring five or more lost workdays.

[1] A message from the Naval Safety Center dated 06 Oct 2009 recently updated the dollar amount thresholds for class A, B, and C mishaps to $2 million, $500 thousand, and $50 thousand respectively, while leaving other criteria such as fatalities, permanent disabilities, lost workdays, and aircraft destruction unchanged (Commander, Naval Safety Center, 2009). The previous definitions listed above applied to all data and studies mentioned in this thesis.

II. LITERATURE REVIEW

A. OVERVIEW

When traditional news organizations report on a tragic aircraft accident, two broad categories of causation are generally cited: mechanical failure and pilot error. Some solace can be found in the former, because we assume a thorough investigation will be conducted to determine the exact component that failed and that appropriate steps will be taken to ensure it is fixed. In contrast, pilot error is a convenient label meant to cover a large number of possible errors in judgment, memory, or skill. It neither conveys the true nature of the error, nor assures us that similar errors can be prevented in the future. Therefore, pilot error is often far more challenging, both to classify and to remedy, than mechanical failure.

B. HUMAN ERROR

Before one can begin to examine human error, it must first be defined. Reason (1990) defined human error as:

> A generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency. (p. 9)

Although it serves as a valid starting point, this definition is a broad statement that covers a vast range of actions and behaviors. It does not address in any detail the reason the intended outcome was not achieved. This is the heart of the matter for all mishap investigators. For safety professionals, determining why errors are made is the first step towards preventing them in the future.

The first step towards determining why errors occur is to understand the different types of human error. The two major categories of errors are failures in planning and failures in execution. In other words, the two principle reasons an error causes the desired outcome to not be achieved is either due to the selection of an inappropriate course of action, or due to some failure in the execution of a course of action (Reason, 1990).

The form of error resulting from selecting an inappropriate course of action is called a mistake (Norman, 1982; Reason, 1990). These planning errors are sometimes referred to as “honest mistakes.” It is important to recognize that for mistakes, the quality of the execution of the selected course of action is not what doomed the decision maker to an undesired outcome; but rather the selection of that particular course of action in the first place. Consider the example of a pilot who crashes while attempting a landing at an airport that is reporting severe weather conditions. Piloting skills likely had little influence on the tragic outcome. The true error was in the decision to attempt a landing in known adverse weather conditions. When the plan itself is flawed, only with a reliance on blind chance or Providence can one expect a positive result.

The second form of error is one of execution, normally called a slip. Norman (1982) distinguished between mistakes and slips by simply stating, “an error in the intention is called a ‘mistake.’ An error in carrying out the intention is called a ‘slip’” (Norman, 1982, p. 378). One type of error in execution related to a slip is a called a lapse. A lapse is a failure of memory storage or retrieval that causes the execution of a course of action to go awry. While slips may be thought of as errors of commission, which are potentially observable by an outsider, lapses are typically errors of omission, which may not be apparent (at least immediately) to anyone but the individual (Reason, 1990). A pilot who activates the engine start switch for the left engine instead of the right is guilty of a slip. In contrast, the pilot who fails to lower the landing gear on final approach has experienced a lapse. The important distinction of slips and lapses from mistakes is that the quality of the plan was not responsible for the outcome, only the failure in its execution.

Although defining mistakes, slips, and lapses is sufficient for a theoretical understanding of human error, it is inadequate for the practical application of mishap investigation and intervention. Simply dividing human error into failures of planning and execution lacks the fidelity needed to provide meaningful insight into preventing the next mishap. Failures in planning and execution can be further divided into more specific errors. Additionally, no mention has yet been made about the conditions surrounding the error and their influence on the individual. External forces and actors could, in fact, set the stage for judgment or execution errors. In search of a more complete picture of human error, several theories and frameworks have evolved to address these concerns.

C. HUMAN ERROR THEORIES AND FRAMEWORKS

Although many studies of cognitive psychology and human error have produced a wide range of theories and frameworks, by and large they are more suited to academic vice practical purposes (Freud, 1901; Norman & Shallice, 1980; Wickens, 1980). To be useful for mishap investigation and intervention, a framework should not require an investigator to use speculation or intuition into the deep processes inside the human mind (Wiegmann & Shappell, 2003). An ideal taxonomy for accident investigation would take both cognitive and external influences into account. To be practical, this framework would guide an investigator through all possible sources of error in a logical and methodical way. The genesis of a framework that could be practically applied by line managers and supervisors began in the field of industrial safety.

D. DOMINO THEORY

In 1931, Heinrich published the first set of principles on industrial safety in a book titled, *Industrial Accident Prevention*. Heinrich's ten axioms of industrial safety were purported to be self-evident truths about the nature of accidents, their causation, and the nature of man-machine interfaces (Heinrich, Peterson, & Roos, 1980). Although subsequent research in the field of industrial safety has called a few of the axioms into question, their basic principles served as the foundation for much of the work that followed (Heinrich, Peterson, & Roos, 1980).

Indeed, the DoD-HFACS taxonomy of human error (discussed in detail later) owes its roots to the early work of Heinrich.

The first of Heinrich's axioms on industrial safety is perhaps the most important, because it is the basis for many frameworks that followed. It states:

> The occurrence of an injury invariably results from a completed sequence of factors– the last one of these being the accident itself. The accident in turn is invariably caused or permitted directly by the unsafe act of a person and/or a mechanical or physical hazard. (Heinrich, Peterson, & Roos, 1980, p. 21)

Although this axiom does not appear groundbreaking on its surface, it does establish the underlying mechanics of the sequence of an accident. Later dubbed the "Domino theory," the analogy provides insight into where to look for the cause of an accident and where to intervene in order to prevent its reoccurrence. In Heinrich et al.'s (1980) early model (Figure 3), the first domino was ancestry and the social environment, which influenced the second domino, the faults of a person. These faults, in turn, constituted reasons for committing unsafe acts (third domino), which led to the accident (fourth domino), and ultimately, the injury (fifth domino). The early Domino model claimed that the unsafe acts and mechanical hazards domino was the lynchpin, which if removed would effectively interrupt the sequence of falling dominos and prevent their tragic conclusion (Heinrich, Peterson, & Roos, 1980).

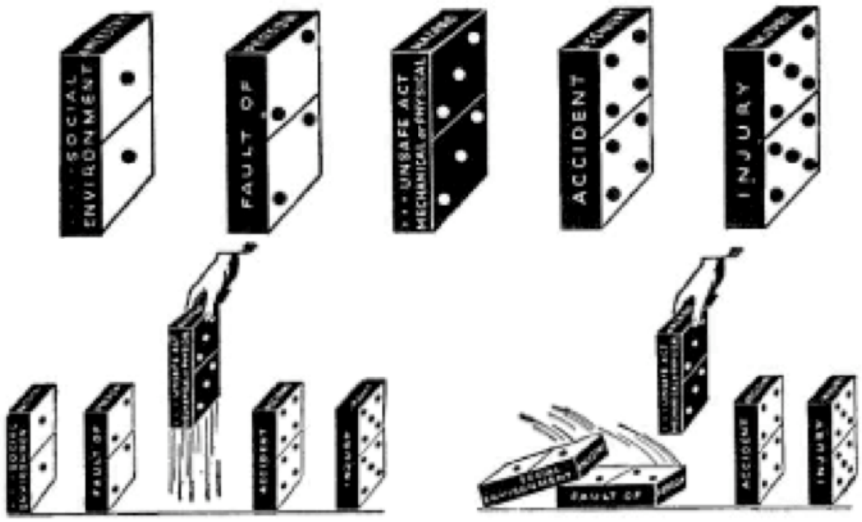

Figure 3. Heinrich’s Domino Theory of Accident Causation (From: Heinrich, Peterson, & Roos, 1980, p.22)

Bird (1974) adapted Heinrich et al.’s Domino theory and revised the levels of the five dominos (see Figure 4). In Bird’s version, the first domino represented lack of control by management. This inadequate control allows an environment in which basic causes of accidents can happen (second domino), such as human, environmental, and job-related factors. These basic causes are the origins of the immediate causes (third domino), which lead to accidents (fourth domino), and ultimately injury and damage (fifth domino). Although immediate causes are the unsafe acts that directly cause an accident, Bird calls them symptoms of the underlying causes in dominos one and two. As Bird states, “when we attack the symptom and do not identify the basic underlying problem, we have not really optimized the potential for permanent control” (as cited in Heinrich, Peterson, & Roos, 1980, p. 26).

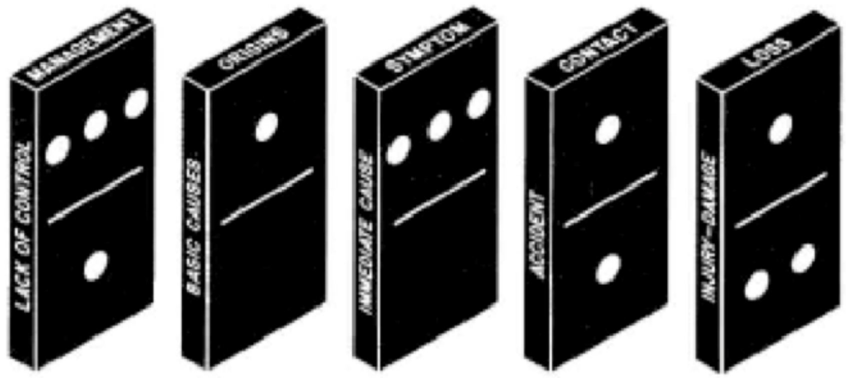

Figure 4. Bird's Adaptation of Heinrich's Domino Theory (From: Heinrich, Peterson, & Roos, 1980, p.24)

The Domino theory provided an important model for accident investigation in the field of industrial safety. The analogy of falling dominos illustrates that accidents do not have a single cause. Every event does not happen in isolation, but rather takes it cue from decisions and practices higher in the organizational structure. Without expanding the scope of accident analysis, safety professionals and managers would be doomed to the futile practice of treating symptoms instead of identifying and addressing the root causes. The need to address the root causes of accidents has become particularly important, as industrial processes and equipment have become more complex.

E. REASON'S "SWISS CHEESE" MODEL

Reason's (1990) book, *Human Error*, is generally regarded as the seminal work on the subject of human error in the last twenty years. The focus of Reason's study is on what he calls "defended systems." These are complex machines, systems, and processes in which automatic safety devices have been incorporated to reduce the occurrence of mishaps. The added complexity of safety mechanisms generally requires the failure of more than one factor (human or mechanical) to result in a mishap. As Reason (1990) states, mishaps "…arise from the unforeseen and usually unforeseeable concatenation of several diverse events, each one necessary but singly insufficient" (p. 197).

1. Errors and Violations

Reason (1990, 1997) classifies the factors that contribute to mishaps into two categories: errors and violations. Although human error is most often the focus of discussion in mishaps, violations are another method by which humans contribute to mishaps. While error includes the unsafe acts due to inattention or poor decision making, violations are those acts committed in defiance of established rules, regulations, or safe practices (Reason, 1990). That the departure from established norms was not done with the intention of causing damage is an important distinction. Reason (1990) labels these transgressions as sabotage, which is not normally a factor in accident investigation. Instead, violations are willful deviations from the rules that do not possess the goal of a destructive outcome.

Violations are divided into two types: routine and exceptional. Routine violations arise from the natural propensity of human beings to take the shortest path between two points (Reason, 1990). A task sequence that is viewed as overly lengthy and complex by an operator will likely be shortened to suit his or her opinion of how it should be done. An indifferent environment and a lack of enforcement of the rules allow this behavior to flourish. If the police choose not to ticket every driver who exceeds the posted speed limit by five miles per hour, drivers will naturally assume the practice is tolerated. Furthermore, in the absence of negative consequences, it is likely that drivers will soon be testing the level of acceptance of a ten mile per hour violation.

Another possible cause of routine violations is necessity. If established procedures or resources prevent the completion of the assigned task, goal-oriented operators will find a way to complete it, even if it involves the violation of procedures. In this case, there is no malicious intent or thrill seeking involved. These violators are hard-working individuals faced with overcoming an impossible task. Unfortunately, as the rules are circumvented, the new unwritten procedure becomes the accepted one, further eroding the legitimacy of written procedures.

Exceptional violations are another instance of an individual who knowingly acts in defiance of the rules. The label as “exceptional” derives from the infrequent and often unique occurrence rather than the magnitude by which a rule was broken. In other words, it is not the heinousness of the violation that makes it exceptional, but rather the infrequency of its occurrence (Wiegmann & Shappell, 2003). An otherwise responsible and competent pilot who executes a high-performance takeoff to “show off” for friends and family who are watching is guilty of an exceptional violation. Exceptional violations are “out of character” for the individual. Thus, their very nature makes them difficult to predict or prevent.

2. Active and Latent Failures

Mishap factors, according to Reason (1990, 1997), are also divided into active and latent failures. Active failures are those errors and violations committed by the operators of the system. Pilots, air traffic controllers, and surgeons are examples of individuals that are responsible for committing active failures. As the front-line personnel, their actions (or lack of) usually have immediate results and are most proximal to the mishap. Historically, these operators have borne the lion’s share of the blame for mishaps. Investigators of the past were often content with establishing what unsafe act caused the mishap and identifying the individual responsible (Reason, 1997). Ending the search for mishap casual factors at this point made intervention strategies relatively simplistic: replace the operator, add a new rule or procedure, and carry on as before. Only in the last 30 years, have safety professionals begun to view front-line operators as the inheritors of unsafe designs, construction, maintenance, and management (Reason, 1990). These surrounding conditions or “latent failures” are now being viewed with more scrutiny.

Latent failures differ from active failures in that they usually occur long before the mishap (Reason, 1990, 1997). Unsafe system design, inadequate maintenance, lack of resources, and poor supervision are examples of latent failures. Although latent failures may result from poor decisions, that is not always the case. Resource allocation decisions may have been made upon sound reasoning at the time, yet they may ultimately result in tragedy as the system or process evolves over time (Reason, 1997). Latent failures are the natural result of complexity and thus are not likely to be easily eliminated.

Reason (1990, 1997) drew an analogy from latent failures to pathogens in the human body. Normally, automatic self-protect measures keep the pathogens and latent failures at bay. These conditions can lie dormant for days, weeks, months, or years until triggered by the correct set of circumstances. When these conditions align, the results are disastrous. It is important to realize that although active failures are generally unique to a specific accident, latent failures may go undetected and sow the seeds of several mishaps until discovered and corrected (Reason, 1997).

The King's Cross fire in the London Underground in 1987 is a tragic example of the role latent failures play in mishaps. Discarded smoking material from a passenger exiting the underground station on a wooden escalator started a fire that resulted in the death of 31 people (Fennell, 1988). A buildup of grease and refuse in the tracks of the escalator provided the tinder that fed flames that quickly spread out of control. Although 45% of the 400 fires recorded in the previous 20 years in the London Underground occurred on these escalators, it was only two years earlier that smoking was banned after a fire at the Oxford Circus station (Fennell, 1988). In spite of knowledge that passengers regularly ignored the ban, the wooden escalators continued in service until the aftermath of the King's Cross fire. Furthermore, the running tracks of the escalators had not been cleaned of grease or debris since their installation in 1939 (Fennell, 1988). These latent conditions undoubtedly contributed to numerous smaller fires until finally corrected in the wake of the King's Cross disaster.

Reason (1990) described a model for active and latent failures within the context of a production enterprise. He stated the production model applies equally well to manufacturing and production facilities as it does to the transportation industry. In either case, the model shares five basic elements:

decision makers, line management, preconditions, productive activities, and defenses. To Reason, these elements are each represented by several barriers to mishaps stacked against one another. As illustrated in Figure 5, latent failures are likely at the corporate decision maker, line management, psychological precursor, and defense levels. Active failures occur as unsafe acts during production activities and as inadequate defenses. Active and latent failures are represented by holes in the barriers to mishaps that must align under a specific set of circumstances to produce an accident. The barriers to mishaps and the holes of active and latent failures have since been represented as slices of Swiss cheese. This "Swiss cheese model" became the underpinning for Wiegmann and Shappell's (1997) HFACS taxonomy discussed in the next section.

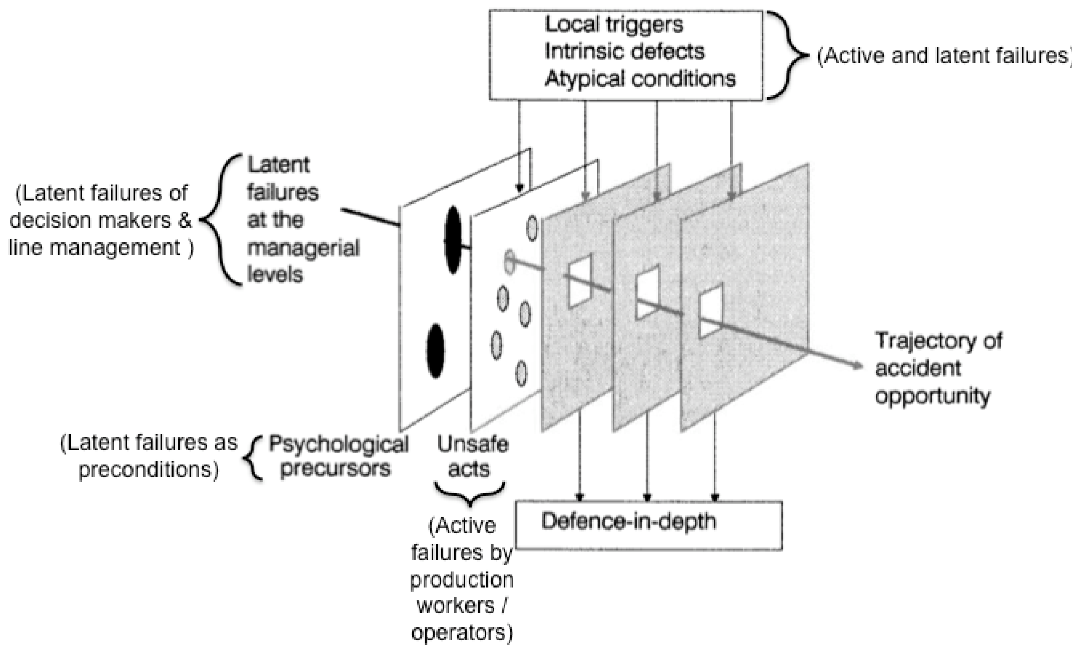

Figure 5. Reason's Swiss Cheese Model (After: Reason, 1990, p. 208)

F. HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM (HFACS)

Using earlier work by Heinrich et al. (1980) and Reason (1990), Shappell and Wiegmann (1997) set out to construct a comprehensive taxonomy of accident causation for use by the Navy and Marine Corps for aircraft accident investigation and analysis. This classification scheme was originally called the "Taxonomy of Unsafe Operations" and has since been expanded and renamed the Human Factors Analysis and Classification System (HFACS). The Defense Safety Oversight Council's Aviation Safety Improvement Task Force adopted the HFACS taxonomy, and adapted it to create a standardized method of investigating, collecting, analyzing, and sharing human factor mishap data across all of the U.S. armed services (Department of Defense, 2005). The resulting taxonomy is called the Department of Defense Human Factors Analysis and Classification System (DoD-HFACS) and is the mandated human error classification system for investigating all DoD mishaps (Department of Defense, 2005).

DoD-HFACS, like the Domino theory, holds that mishaps are the result of a sequence of events and failures throughout an organization (Department of Defense, 2005). DoD-HFACS also uses Reason's (1990) concept of latent failures as the precipitating influences of unsafe acts that directly cause accidents. Specifically, DoD-HFACS looks to define and further categorize Reason's latent failures in order to aid accident investigation and analysis. To do this, DoD-HFACS identifies four layers of active and latent failures: acts, preconditions, supervision, and organizational influences. Figure 6 illustrates these four layers, and how latent failures can align to allow a mishap.

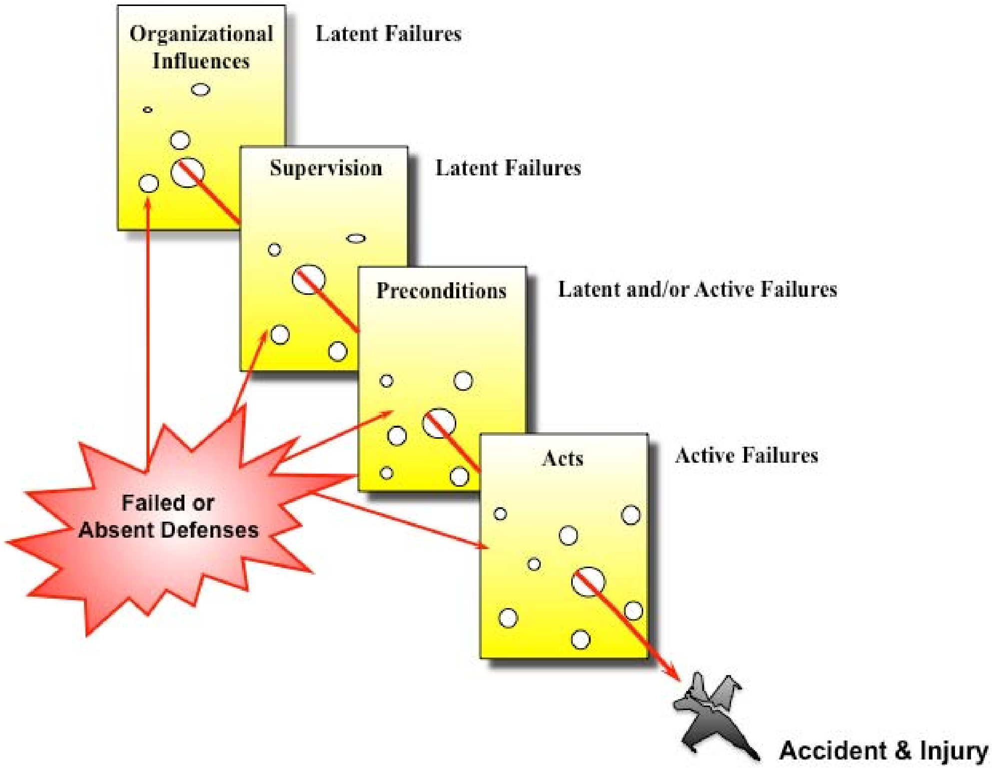

Figure 6. The HFACS Swiss Cheese Model of Accident Causation Adapted From Reason, 1990 (After: Wiegmann and Shappell, 2003, p.47)

Each layer is made up of several categories of related errors and failures. These categories are further parsed into individual failures, called nanocodes, which classify the specific instance of human error. It is the nanocodes that will be identified as the contributors to a mishap. Safety professionals can then compile these nanocodes across mishaps and over time for further in-depth analysis. Figure 7 shows the four levels and their corresponding categories in DoD-HFACS. Each level and its respective categories will be briefly discussed. For a complete listing and description of the 147 DoD-HFACS nanocodes, see the Appendix, taken from the DoD-HFACS Quick User's Guide (Department of Defense, 2005).

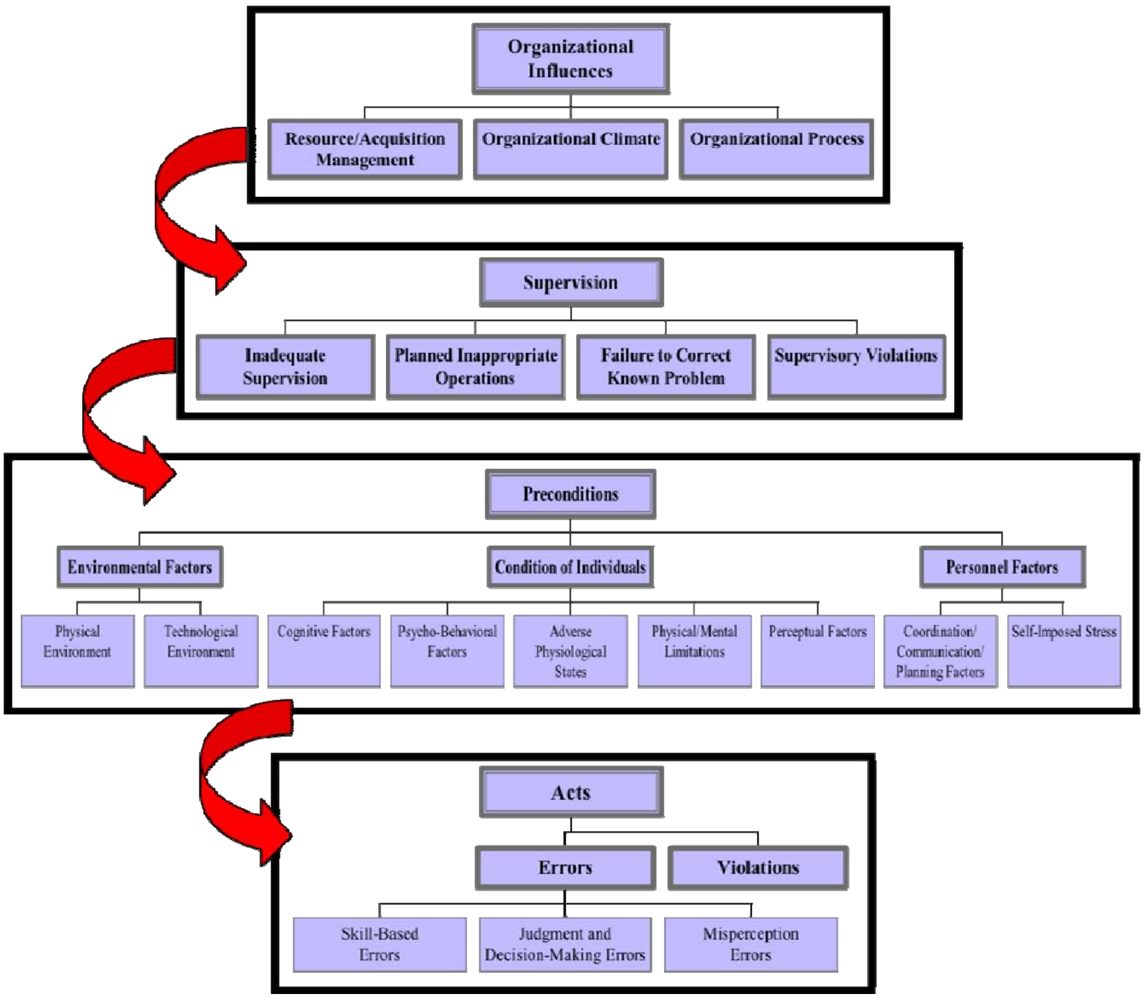

Figure 7. DoD-HFACS Taxonomy (From: Department of Defense, 2005, p.5)

1. Acts

The first level of DoD-HFACS (see Figure 8) is the one most closely associated with mishaps. Acts are the final actions or failures of action that can be said to be most directly responsible for the accident. It is these acts that traditional mishap investigation techniques have focused on most intensely (Shappell & Wiegmann, 2001). DoD-HFACS, like Reason (1990), divides acts into two broad categories, errors and violations. Errors refer to well-intentioned actions that did not achieve the desired outcome, whereas violations are actions that are in defiance of established rules and regulations (Shappell & Wiegmann, 2000). The error category is further broken down into three types: skill-based errors, judgment and decision-making errors, and perception errors.

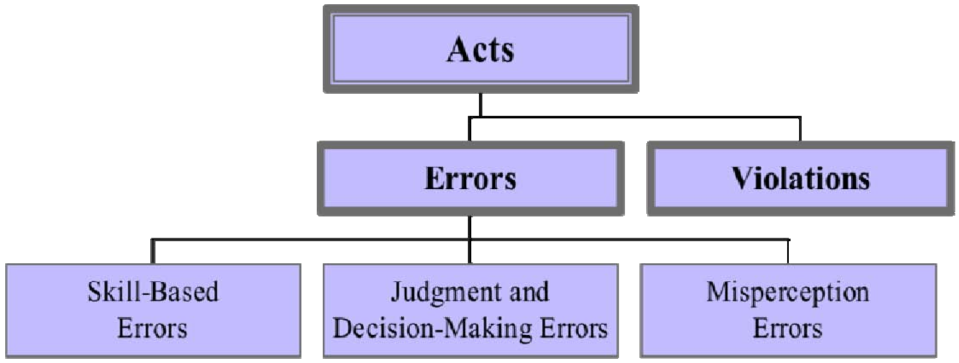

Figure 8. Categories of Acts of Operators (From: Department of Defense, 2005, p. 6)

a. Errors

(1) Skill-based Errors. Skill-based errors are those that occur while an individual is executing a routine and highly practiced task (Department of Defense, 2005). The DoD-HFACS identifies six specific skill-based error nanocodes in the acts level of mishap investigation. Skill-based actions, such as driving a car or flying an aircraft are learned behaviors that become ingrained, so as to not require active concentration. As such, these activities are prone to Reason's (1990) slips and lapses of attention and memory (Wiegmann & Shappell, 2003). Attention failures, or slips, are common in everyday life. One common example is a driver who wanders out of his or her lane on the highway while tuning the radio or adjusting the air conditioning. Recent legislation restricting or prohibiting the use of cell phones or texting while driving are examples of interventions aimed at preventing these types of skill-based errors.

Memory failures, or lapses, are another example of skill-based error. Missing checklist items, losing one's place, and forgetting intentions are common lapses (Wiegmann & Shappell, 2003). Memory failures can range from innocuously forgetting to take the trash can out to the street on the appointed trash day, to tragically forgetting to lower the landing gear on final approach.

(2) Judgment and Decision-Making Errors. Judgment and decision-making errors are those in which the errors are committed in the planning or selection of a course of action. This error type is what Reason (1990) called a mistake. Pilots who choose to perform the wrong emergency procedures, or who do not properly assess the risks of a selected course of action are guilty of these “honest mistakes.” DoD-HFACS contains six nanocodes to capture specific judgment and decision-making errors in mishaps.

It is important for safety professionals to distinguish between decision-making and skill-based errors, because correct identification is necessary to construct the proper intervention. If a pilot fails to perform a procedure correctly, that is a skill-based error. If the procedure selected by the pilot is inappropriate to the situation at hand, then a decision-making error has occurred. In the former case, memorization, practice, and repetition might be the remedy. In the latter, deeper understanding of the aircraft systems, scenario-based decision training, and experience would likely be more effective intervention strategies.

(3) Perception Errors. The third type of error is not one of planning or execution, but rather perception. A pilot’s plan and execution both hinge on the quality of the information available. If the pilot’s view of reality differs from ground truth, it should be no surprise that errors are likely. In aviation, spatial disorientation that arises from visual or vestibular illusions often cause pilots to misjudge altitudes, airspeeds, distances, and even which direction is up. Although these illusions are well known and the subject of an extensive amount of training, mishaps continue to occur from pilots’ incorrect responses to them (Wiegmann & Shappell, 2003). DoD-HFACS incorporates a single nanocode to account for these incorrect responses to perceptual illusions.

b. Violations

The final category of active failures at the acts level is violations. Unlike errors, violations do not occur due to lapses in memory, attention, or judgment. Instead, violations result from intentionally breaking a known rule or instruction (Shappell & Wiegmann, 2000). DoD-HFACS incorporates a nanocode for each of the three different types of violations.

The first type of violation is what is referred to as a "work-around violation." In this violation, the risks associated with committing the violation were considered, and committing the violation was determined to be the best solution (Department of Defense, 2005). This violation may be unique to a particular mishap or may be common within a community that recognizes that the established rules do not permit the best course of action. One example of when work-around violations can occur is when written maintenance procedures are incorrect or inadequate. When faced with this scenario, experienced maintenance personnel may choose to do what they perceive is necessary even if it is in conflict with the written instructions.

The other two types of violations are routine and exception violations as previously defined by Reason (1990). It is important to note the difference between work-around violations and routine violations. Although work-around violations may take place routinely, the consequences and risks associated with them have been considered. In spite of these risks, the individual chose to continue in order to accomplish the mission. Routine violations, in contrast, needlessly expose the aircraft and crew to risks that serve no greater purpose (Department of Defense, 2005). The case of ignoring steps in a written maintenance procedure merely to "cut a few corners" and save time would be classified as a routine violation if it occurred regularly. The lack of necessity is what distinguishes this case from a work-around violation.

2. Preconditions

Although determining the acts that caused an accident are important, Wiegmann and Shappell (2003) liken these acts to the symptoms of a disease. Developing interventions for unsafe acts is likely to be as effective as treating the symptoms of a chronic illness. To understand the root cause and intervene where it will be most successful, safety professionals must look farther upstream. The preconditions that preface the unsafe acts in a mishap are critical to examine. Their influence may range from very little to the point, in extreme cases, where it would have actually been surprising if an accident had *not* occurred.

To capture the numerous factors that set the stage for unsafe acts, DoD-HFACS lists 92 nanocodes at the preconditions level, over 60% of the entire set of 147 nanocodes. The preconditions level (see Figure 9) takes into account a variety of influences that are categorized into three main types: condition of individuals, personnel factors, and environmental factors. In many cases, environmental and personnel factors strongly influence the condition of individuals. For example, a precondition of self-imposed stress may adversely affect a cognitive factor in the condition of the individual. In this way, it is easy to see that the interaction of several preconditions may be the circumstances that set the stage for an unsafe act.

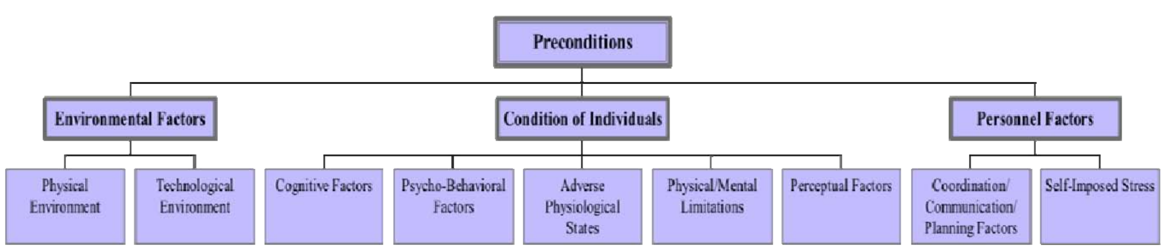

Figure 9. Categories of Preconditions for Unsafe Acts (From: Department of Defense, 2005)

a. Condition of Individuals

The condition of an individual has a strong influence on the outcome of any operation that individual may be performing. Laws against driving under the influence of drugs and alcohol are logically based upon such a notion. However, the range of factors that goes into making up the condition of the individual are perhaps more diverse than one might first think. DoD-HFACS identifies five broad categories that affect individual performance: cognitive factors, psycho-behavioral factors, adverse physiological states, physical/mental limitations, and perceptual factors. Each of these categories, in turn, has a list of nanocodes detailing the specific factors of influence.

(1) Cognitive Factors. The eight nanocodes associated with cognitive factors are concerned with the attention or awareness failures that affect perception or performance (Department of Defense, 2005). These failures include: not paying attention, paying too much attention to the wrong thing, and distraction or interruption during a task. Essentially, these types of failures are related to the mental processing of information.

(2) Psycho-Behavioral Factors. Whereas cognitive factors concern mental processes, the 15 nanocodes of psycho-behavioral factors are related to personality traits, problems, and disorders of individuals (Department of Defense, 2005). These factors range from clinical psychological disorders, to overconfidence, and motivational burnout. The psycho-behavioral factors category covers a lot of conditions that, in essence, try to determine the motivation behind an individual's actions. This category is often used to explain acts in the decision-making and violations categories and determine why the individuals made the choices they did.

(3) Adverse Physiological States. The 16 nanocodes of adverse physiological states address the medical and physiological factors that degrade human performance (Department of Defense, 2005). These factors include potentially debilitating states such as G-induced loss of consciousness, dehydration, hypoxia, jet lag, and others. As might be expected, these episodes can physically prevent a pilot or operator from performing at the level required for safety.

(4) Physical/Mental Limitations. The five nanocodes that encompass physical and mental limitations refers to an individual's capacity to cope with a given situation. These limitations can be physical in nature, such as anthropomorphic body size or biomechanical strength and reach. If a pilot lacks the physical strength to manipulate manual flight control surfaces when the hydraulic-assisted control function fails, it will come as no surprise when that pilot fails to maintain aircraft control.

Mental limitations are also important to consider in the condition of individuals. One such limitation is memory capacity. If the emergency procedures that must be committed to memory are too lengthy, it is likely that steps will be forgotten and a tragic end will follow.

Although these physical and mental limitations may seem similar to those found in cognitive factors and adverse physiological states, there is an important distinction. Physical and mental limitations are more permanent in nature. Whereas G-induced loss of consciousness and distraction are temporary and often preventable factors, the memory capacity or physical strength of an individual is not quickly or easily changed.

(5) Perceptual Factors. The perceptual factors category is comprised of 11 nanocodes that catalogue degraded sensory inputs (Department of Defense, 2005). These include recognized and unrecognized spatial disorientation and various other vestibular and visual illusions. The acts level also addresses the issue of perception. The difference is that at the

precondition level, these perceptual factors are the illusions themselves, while the perception error at the acts level refers to the operator's incorrect response to them.

b. Personnel Factors

Just as the condition of the individual can influence whether that individual commits an unsafe act, there are some things individuals do to themselves that adversely affect their own condition (Shappell & Wiegmann, 2001). These are called personnel factors in DoD-HFACS. The two categories within personnel factors are: coordination/communication/planning factors and self-imposed stress.

(1) Coordination/Communication/Planning Factors. This category can be thought of as the group personnel factors that influence the condition of individuals. These 12 nanocodes cover a range of activities in which aircrew, air traffic controllers, and other personnel outside the cockpit must effectively communicate and coordinate their activities for safe and successful operations. The Navy's Crew Resource Management (CRM) program consists of annual training on the specific skills needed to be effective. These skills include decision-making, assertiveness, mission analysis, communication, leadership, adaptability and situational awareness. Failures related to these skills often adversely affect the condition of individuals, causing confusion, distraction, and task over-saturation.

(2) Self-imposed Stress. Self-imposed stress is the category that identifies the factors that individuals contribute to their own condition. As opposed to physical or mental limitations, these factors are generally temporary and preventable. An individual who chooses to stay up late, subsist on candy bars and beer, and has never seen the inside of a gym is not likely to be mentally and physically sharp for work in the morning. DoD-HFACS has six nanocodes to catalogue these stressors that influence the conditions of an individual and contribute to mishaps.

c. Environmental Factors

Beyond the influences individuals have on their own condition, external forces also play a role. DoD-HFACS identifies two broad categories of environmental factors that can influence the condition of individuals and promote unsafe acts: physical environment and technological environment.

(1) Physical Environment. Physical environment encompasses a wide range of factors that define the space in which operations take place. These include weather conditions, lighting, temperature stressors, noise, vibrations, and the operations of other aircraft in the vicinity. It is important to note that these environmental factors can be both external and internal to the immediate environment of the operator. Smoke and fumes or heat stress in the cockpit are just as much a danger as extreme outside temperatures and visual obscurants such as clouds, dust, and haze. DoD-HFACS incorporates 11 nanocodes related to these factors in the physical environment.

(2) Technological Environment. Eight nanocodes in DoD-HFACS cover the mishap contributors that are traditionally the focus of human factors engineering. This field encompasses the physical and cognitive interfaces of human and machine. Just a few examples of human-machine interface design problems include whether displays are readable in bright sunlight, if controls are within reach of the intended operator, and if the operating system is intuitive to use. Issues such as these represent the types of barriers that must be overcome by the operator to use the system. However, these technology issues may not be present for every user. It is the mismatch of user and system that is at the heart of the problem. Poor design is a great example of one of Reason's (1990) latent failures that lie dormant until the right set of circumstances occurs before it causes an accident.

3. Supervision

Like Reason (1990), DoD-HFACS identifies latent failures at the supervisory level. The reach of supervisors far exceeds that of individual operators. While one error by a pilot may cause one mishap, one supervisory failure may set the stage for many. The goal of investigating the failures of managers and supervisors is not to relieve pilots and operators of accountability for their actions (Department of Defense, 2005). Rather, it is to ensure that the leadership provided is adequate, appropriate, and responsive. DoD-HFACS identifies four categories at the supervisory level that may contain latent failures: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations (see Figure 10).

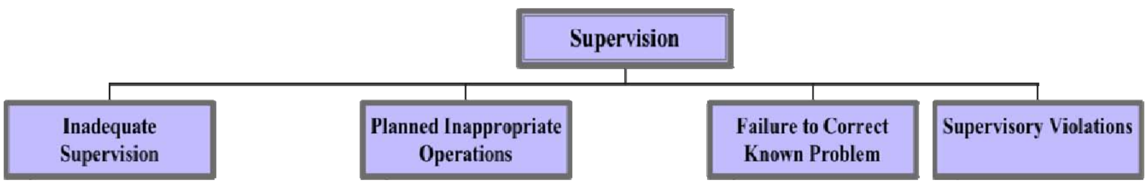

Figure 10. Categories of Unsafe Supervision (From: Department of Defense, 2005)

a. Inadequate Supervision

Every supervisor is tasked to provide the tools of success to those under them (Wiegmann & Shappell, 2003). Guidance, training, mentorship, and oversight are critical functions of any supervisor. The lack of any of these essential elements can easily allow the operators to function in an unsafe manner. If a pilot is not provided the proper training or policy procedures for dealing with likely emergency scenarios, it should not be surprising when a mishap occurs. Likewise, a supervisor who does not stay in touch with what his aircrews are doing has little chance to develop appropriate policy, provide helpful guidance, and ensure dissemination of information throughout the organization.

Inadequate supervision that fails to identify hazards, control risks, and provide appropriate guidance and oversight are captured by six nanocodes in DoD-HFACS (Department of Defense, 2005).

b. Planned Inappropriate Operations

The category of planned inappropriate operations covers a range of decision-making failures by supervisors. Included in the seven nanocodes in this section of DoD-HFACS are choices that must be made by supervisors on a daily basis. Supervisors must regularly assign tasks to individuals and individuals to function together as a team. These assignments should be based on several factors including: experience, personality, knowledge, skills, and qualifications. Selection of personnel, as well as the tempo of operations established, should also take into account the condition of the operators including factors such as illness, distraction, and fatigue level. A supervisor, who assigns two inexperienced crewmembers a difficult and unfamiliar mission, effectively sets them up for failure (Department of Defense, 2005). Large differences in rank or authority and conflicting personalities can also lead to an increased chance of human error. An effective supervisor must consider all of these factors when assigning individuals to teams and tasks.

c. Failure to Correct Known Problem

A special type of failure at the supervisory level is the failure to correct a known problem. This failure occurs when the supervisor was aware of an unsafe condition in the form of equipment, personnel, or policy and allowed operations to continue anyway. DoD-HFACS has two nanocodes in this category: personnel management and operational management. Personnel management refers to a failure to identify and correct inadequate or risk-seeking pilots. When such a pilot is involved in a mishap, usually no one seems surprised (Shappell & Wiegmann, 2000). Yet even without the benefit of hindsight, indicators of thrill-seeking or unskilled pilots are often visible to supervisors who fail to take action.

The operations management nanocode is designed to capture the failure of supervisors to provide guidance and correct unsafe practices or conditions. A failure of supervisors to step in and correct these unsafe practices implies they are condoned. For this reason, routine violations at the acts level are likely to be closely associated with this type of failure.

d. Supervisory Violations

The last category in the supervisory level is supervisory violations. Like violations at the acts level, this category relates to willful disregard for rules, regulations, and higher authority (Wiegmann & Shappell, 2003). DoD-HFACS lists four nanocodes at this level. One such failure type is the supervisor's authorization of operators to conduct missions for which they are not qualified. A supervisor that allows a pilot who has not passed his annual safe for flight checkride to continue flying is one such example. Perhaps the most egregious case is when a supervisor specifically directs a subordinate to violate a regulation. Whether born from a risk-seeking personality or an overinflated ego, a supervisor with a penchant for disregarding established rules and regulations is inviting disaster.

4. Organizational Influences

The top level of failures in DoD-HFACS is organizational influences. The organizational level is distinguished from the supervisory level by its greater sphere of influence. Whereas an operator may have one or two levels of supervision that directly influence his or her daily operations, the organizational level represents a broader perspective. This level consists of the top level of leadership at the corporate headquarters or military service branch. Reason (1990) called this level the "decision makers" because it represented the highest echelons of leadership who make the large-scale choices on organizational policies, missions, and the allocation of resources. Although the decisions made at this level are sometimes difficult to directly attribute to the causation of a mishap, they certainly provide the circumstances and environment in which one can occur. Figure 11 illustrates the three categories of organizational influences in DoD-HFACS: resource/acquisition management, organizational climate, and organizational process.

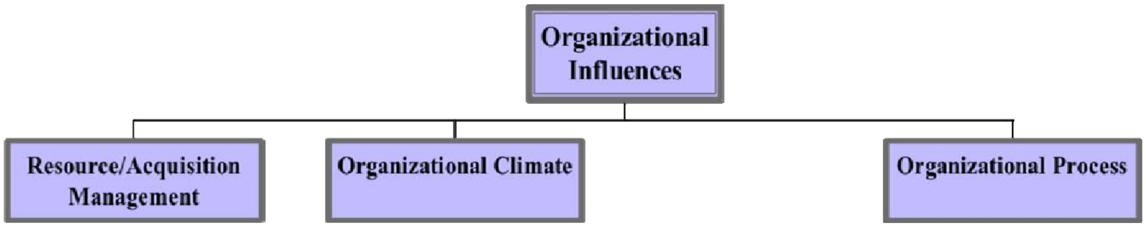

Figure 11. Categories of Organizational Influence (From: Department of Defense, 2005)

a. Resource/Acquisition Management

The nine nanocodes of DoD-HFACS for resource/acquisition management cover failures in top-level decisions regarding manning, personnel selection, equipment design and condition, and funding priorities. Military services often compete with each other for increasingly scarce congressional funds. As a result, not every desire of the service is fulfilled. Decision makers must perform tradeoffs among various competing priorities in order to effectively carry out their mission. However, those tradeoffs sometimes come at a price. If the Navy is unable to afford to man their ships with enough Sailors, it is easy to see how accidents can occur. Likewise, the type of personnel assigned to a ship can greatly influence its propensity for a mishap. Manning a ship entirely with "green" recruits would also be a recipe for disaster. Finally, if the Navy cannot afford to properly maintain the ship or build one appropriate to the assigned mission, success will not be forthcoming. The challenge for senior leaders is that resource allocation decisions that are fiscally sound may, in fact, be latent failures awaiting their opportunity to contribute to a mishap.

b. *Organizational Climate*

Organizational climate refers to the characteristics that define how an organization conducts business. The five nanocodes in DoD-HFACS contain such traits as organizational structure, incentives, beliefs, values, and culture. While some policies and structures are formalized, such as a chain of command, others, such as what types of individuals get selected for promotion, are not. Although sometimes difficult to quantify, the policies and practices of an organization reveal the underlying culture that drives its behavior. As individuals are influenced by that culture, it can be either a positive or a negative force. Identifying those elements of the organizational climate that might push individuals into a corner and force an ill-fated decision is the purpose of this category of DoD-HFACS.

c. *Organizational Process*

The final category at the organizational level is called organizational process. These six nanocodes of DoD-HFACS cover the operations, procedures, and oversight of the organization (Department of Defense, 2005). The operations category refers to the pace of operations, schedules, and time pressure as set at the highest levels. Deployment schedules that leave little time for long-term maintenance, upkeep, or training are an example of an operational process that might lead to the preconditions for a mishap. The procedures category refers to the standards, rules, and regulations established by higher authority as the “right way” to do business. The consequences of errors encoded in these procedures are not only tragic in their own right, but undermine the confidence individuals place in such regulations in the future. Finally, the oversight category refers to organizational-level monitoring and management of risk. This includes safety programs and independent inspections by observers outside the normal chain of command. The emphasis, or lack thereof, an organization places on oversight can have a significant influence on the quality and safety of the work environment (Department of Defense, 2005).

G. USING DOD-HFACS IN ACCIDENT INVESTIGATION

In order to apply DoD-HFACS in a mishap investigation, it is generally helpful to start at the time of the accident and work backwards (Wiegmann & Shappell, 2003). Traditionally, this is how accident investigations have been performed. As a human error that contributed to a mishap is discovered, it is natural to ask why it occurred. Thus, if the investigator identifies an unsafe act, it is logical to look for a precondition that led to it. Likewise, supervisory conditions might have set the tone that created or allowed the preconditions to exist. Finally, the larger organization may have influenced the types of individuals who were promoted to supervisory positions or created the culture that rippled down to the lower levels, coloring the decisions and actions of all involved.

Therefore, a prudent investigator should generally look farther up the hierarchy of DoD-HFACS to examine if other factors were at play. This begs the question of when the search for causal factors should end. Carried to the extreme, it can be said that if the Navy chose not to operate any aircraft, it would not have any aviation mishaps. Reason (1997) cautioned against the over zealous search for contributing factors in mishap investigation. He listed three criteria to consider in the determination of contributing factors: a) did the factor add to the understanding of the causes or events, b) contribute to the prediction of future accidents, or c) contribute to remedial efforts to reduce future occurrences of accidents. As these are substantively the goals of any effective safety program, it important that investigators are mindful of them as they search for casual factors.

H. APPLICATIONS OF HFACS

One advantage of HFACS is its ability to comprehensively code data from mishap investigations for later analysis. The ultimate goal of any such analysis is to determine where safety professionals should allocate their resources for the greatest benefit. Since its inception, researchers in pursuit of answering questions about the nature of aircraft accidents have successfully applied HFACS towards that goal.

Shappell et al. (1999) used HFACS to examine 151 Naval Aviation mishaps between 1991 and 1997. Using the findings from the original mishap investigations, it was discovered that approximately one third of all mishaps involved at least one violation of established rules and regulations. Although this was a surprising result to many senior leaders in the Navy, the full severity of the problem was not fully realized until a similar analysis of Army and Air Force mishaps was conducted. Wiegmann, Shappell, and Fraser (2002) used HFACS to reveal that violations were only associated with roughly one quarter of the aviation mishaps in the Army, and less than ten percent in the Air Force. This comparison brought into sharp relief the culture of tolerance in Naval Aviation for bending the rules during those years (Wiegmann & Shappell, 2003). As a result, the Navy and Marine Corps instituted intervention strategies aimed at increasing the enforcement of the rules and holding pilots and their commanding officers accountable for breaking them. Subsequent HFACS analysis of mishaps between 1997 and 2000 revealed a decline in the frequency of violations that more closely matched Air Force levels (Wiegmann & Shappell, 2003). Thus, HFACS was demonstrated to be useful in diagnosing a safety issue, and providing a metric for the measurement of intervention effectiveness.

The ability of HFACS to capture and categorize types of human error for analysis gives researchers the opportunity to ask very specific questions about the causes of mishaps and track the effects of interventions over time. In another example of this type of analysis, Wiegmann et al. (2005) used HFACS to examine mishaps in the general aviation community. This study used mishap data from the National Transportation Safety Board (NTSB) database from 1990 to 2000, which was then coded into HFACS. The researchers wanted to know which unsafe acts were responsible for the largest percentage of accidents, if those percentages changed over time, and if there were differences between the unsafe acts associated with fatal and non-fatal accidents.

Using HFACS, Wiegmann et al. (2005) discovered that skill-based errors were identified as a contributor in 80% of all general aviation mishaps. This was far above the second-place unsafe act, decision errors, which was identified as a contributor in only 30% of mishaps.[2] The researchers noted that the relative percentage of unsafe acts was stable across time, but there was a distinct difference between fatal versus non-fatal accident contributors. The percentage of all unsafe acts was the same for both fatal and non-fatal accidents, except for violations. Violations were four times more likely to be associated with fatal accidents than non-fatal accidents. In practical terms, if a pilot's violation of the rules resulted in an accident, it was far more likely to result in a fatality than not (Wiegmann et al., 2005).

I. SUMMARY

Human error continues to play a large role in mishaps in Naval Aviation and elsewhere. Safety professionals and senior leaders struggle to determine where the root problems lie and how best to intervene. Unfortunately, intervention strategies are often selected based on unavoidable biases of the decision makers. The most recent mishap causes or those that garner the most public attention often lead to knee-jerk interventions that may or may not get at the underlying problem. Additionally, the intervention strategies developed tend to be colored by the experiences of those who generate them. For example, engineers tend to develop engineering solutions; training specialists tend to develop training solutions, and so on. Finally, it is often difficult to follow up after interventions are made to determine if improvements were made. Mishap prevention strategies based on facts, not intuition, that can be objectively evaluated, stand a much greater chance of long-term effectiveness.

[2] In mishap reports, several factors are often identified as contributors. Therefore, percentages of contributing factors do not add up to 100%.

Sometimes, organizational level factors such as culture, resource allocation, and equipment design have substantial influences on mishaps. These factors are often hard to identify and difficult to change, particularly in the near term. New aircraft are only introduced to the fleet every 20 years or so. Although designers would ideally like to improve safety in each new generation, it can be difficult to remember lessons learned from long ago. If mishap causes can be categorized in such a way as to compile like factors together over time, safety organizations can assemble and maintain a database of errors that need to be addressed by the designers of the next generation of aircraft.

DoD-HFACS represents a serious effort in identifying and addressing the problem of human error. The ability to apply statistical analysis to a standardized database across services promises to provide decision makers with better information. Additionally, DoD-HFACS affords the ability to examine the effectiveness of interventions. Finally, DoD-HFACS can serve as a knowledge repository from which future aircraft designers can draw upon to increase the safety of their creations. The next chapter will examine DoD-HFACS mishap data collected by the Naval Safety Center to determine the most common sources of human error in Naval Aviation mishaps.

III. EXAMINATION OF NAVAL AVIATION CLASS A MISHAP DATA

A. BACKGROUND

> A naval aviation mishap signals a failure in the Naval Aviation Safety Program. It is evidence we failed to detect and eradicate the hazards which caused this mishap before it was too late. It is not too late, however, to keep it from happening again – which is why we investigate aviation mishaps with such vigor. (Chief of Naval Operations, 2007, p. 6–1)

The first step in developing mishap intervention strategies is to determine what is causing mishaps in the first place. This analytical effort will examine recent Naval Aviation mishap data to determine the human errors that are most frequently contributing to mishaps. Logically, these errors should be the focus of any efforts to develop intervention strategies for current aircraft, but they also bear consideration by the designers of future generations of aircraft. Systems that fully appreciate and accommodate the strengths and weaknesses of the human user can offer more effective defenses against errors. However, in order to begin it must be first known where the problem lies.

B. OBJECTIVE

The objective of this analytical effort is to determine the most frequent human errors that contribute to Naval Aviation class A mishaps. These tragic accidents represent over $1 million in damage, permanent total disability, and/or the loss of life. In addition to determining the top error types across all Naval Aviation mishaps, analysis will be conducted between services (Navy and Marine Corps) and between individual communities within each service (F/A-18 and helicopter). This analysis will be conducted in order to ascertain the influence of differences in cultures, missions, and aircraft systems on the type of human factors errors committed. Identifying the differences between communities is critical to the design of intervention strategies that are tailor-made to the unique circumstances of each platform and service.

C. DATA COLLECTION

The Naval Safety Center collects investigation reports from all Naval Aviation flight mishaps and maintains a database of casual factors for ongoing analysis and evaluation. In support of the adoption of DoD-HFACS by all the armed services, the Commander, Naval Safety Center issued a directive requiring all future Naval Aviation mishap reports to use DoD-HFACS for the coding of causal factors (Commander, Naval Safety Center, 2009). Additionally, many of the Naval Safety Center's mishap database archives are undergoing recoding into DoD-HFACS. These two efforts are aimed at building and maintaining a repository of mishap data that is comparable across time to determine if mishap causal factors change in response to safety efforts. In addition, the use of a standardized taxonomy like DoD-HFACS allows data to be shared and compared across services.

Prior to the adoption of DoD-HFACS, Naval Aviation mishap reports were coded in a "Who/What/Why" format. The conclusion of the mishap investigation report summarized the factors found to be causal to the mishap by listing codes for "who" was involved in a particular factor, "what" the factor was, and "why" it contributed to the mishap. The Naval Safety Center's instruction governing the investigation of mishaps listed over 550 standard "who" codes to be used to identify persons involved with a mishap causal factor. For example, a pilot at the controls was coded as "101," or a commanding officer was coded as "40101." The instruction also listed almost 500 "what" codes for identifying and classifying various causal factors. As examples of this coding scheme, "11509" was used to record a misuse of brakes, and "11810" indicated a loss of situational awareness.

Finally, over 300 “why” codes were used to provide a reason the causal factor occurred. Examples of these codes include “20413 passed over for promotion” and “40202 indecision”.

The recoding of existing mishap data from “Who/What/Why” into DoD-HFACS is an ongoing-effort at the Naval Safety Center. Due to the large number of mishaps archived, only those mishaps that involve aircraft platforms that will be operational for the foreseeable future are being recoded into DoD-HFACS. These platforms are fixed-wing strike fighters such as the F/A-18 Hornet and AV-8B Harrier, and helicopters such as the H-60 Seahawk, H-53 Super Stallion, H-46 Sea Knight, UH-1 Huey, and AH-1W Cobra. An aviation experimental psychologist with a Ph.D. in human factors and extensive experience in HFACS who is assigned to the Naval Safety Center is responsible for the recoding process. The original flight mishap report, aeromedical analysis, and the final endorsement from the Naval Safety Center are used to determine the appropriate set of DoD-HFACS nanocodes that are appropriate to each mishap. The recoding process began with the most recent data available and is proceeding through previous years in order. As of this writing, DoD-HFACS conversion has been completed for mishaps going back to FY2000.

This first analytic effort utilizes all the class A flight mishap data from the Naval Safety Center that has been recoded into DoD-HFACS. The resulting data pool available for analysis contains 141 Navy and Marine Corps class A flight mishaps containing 831 DoD-HFACS nanocodes. Table 1 summarizes the Naval Safety Center data available for analysis between FY2000 and FY2008, including number of mishaps, flight hours, mishap rate per 100,000 flight hours, and total number of DoD-HFACS nanocodes recorded as contributing to a mishap.

Table 1. Naval Safety Center Mishap Data

	USN		USMC						USN/ USMC Combined
Aircraft	**F/A-18**	**H-60**	**F/A-18**	**AV-8B**	**H-53**	**H-46**	**UH-1**	**AW-1W**	**All listed**
Mishaps	47	16	23	24	7	9	8	7	141
Flight Hours	1,823,327	1,164,774	814,914	321,643	378,971	528,491	196,817	378,750	5,607,687
Mishap Rate	2.58	1.37	2.82	7.46	1.85	1.70	4.06	1.85	2.51
DoD-HFACS Nanocodes	227	134	62	129	99	61	70	49	831

D. DATA ANALYSIS METHOD

Before the data can be analyzed, a reasonable basis of comparison must first be established. Comparing across different services, aircraft types, and platforms is difficult for several reasons. Differences in aircraft type, numbers, mission, culture, and operating environment all play a role in influencing the occurrence of mishaps. Additionally, the amount of risk exposure to mishaps is greater in services or platforms that fly more often than others. One metric commonly used by the Naval Safety Center for quantifying the frequency of mishaps is mishap rate. Mishap rate is the average number of mishaps that occur per 100,000 hours of flight time. A mishap rate is computed by dividing the number of mishaps that have occurred by the number of flight hours flown in a given period and multiplying by 100,000. Mishap rates give a relative measure of risk of mishaps that can be compared across squadrons, aircraft type, or communities and tracked from year to year.

A metric for comparison of DoD-HFACS errors between communities is a difficult challenge. One mishap can have several DoD-HFACS nanocodes, categories, and levels associated with it. As an example, imagine a pilot who fails to correctly follow a checklist because he is stressed about his upcoming annual performance evaluation from his commanding officer with whom he has had repeated personality conflicts. The resulting mishap can be associated with at least one nanocode in the acts, preconditions, and supervisory levels. Once other factors such as the influence of other crewmembers or air traffic controllers are factored in, it is easy to see that there is no set number of nanocodes that could be associated with any given mishap. Simply adding up occurrences of DoD-HFACS nanocodes to gauge their frequency is insufficient.

In order to standardize DoD-HFACS error frequency across mishaps, a rate similar to mishap rate will be used as a basis of comparison. The number of occurrences of a particular DoD-HFACS nanocode divided by the number of flight hours in a given period and multiplied by 100,000 yields the rate of occurrence of that nanocode per 100,000 flight hours. The rate of any given nanocode is likely to be less than the overall mishap rate. This is logical because not every nanocode occurs in every mishap. Likewise, if the rates of all the individual nanocodes were added together, the result would likely be much higher than the mishap rate because each mishap typically has several nanocodes associated with it. The purpose of computing an occurrence rate for nanocodes is to identify those that occur most frequently in mishaps. Essentially this method makes it possible to compute the rate of occurrence of specific error types (severe enough to contribute to a mishap) per 100,000 flight hours. Using rate per 100,000 flight hours provides a baseline to allow equal comparisons regardless of how many aircraft or flight hours a particular community flies.

Although the rate of occurrence of individual DoD-HFACS nanocodes is interesting, their fine granularity can dilute the bigger picture. For example, in the skill-based error category at the acts level, two nanocodes are very similar: “AE102 Checklist Error” and “AE103 Procedural Error”. This similarity can cause a problem with the reliability of mishap investigators to consistently assign the appropriate code to a human factors error. If a pilot fails to lower the landing gear and a mishap results, that error could be coded as a procedural error. The pilot failed to correctly lower the landing gear as a part of the landing procedure.

However, the lowering of the landing gear is a step on the landing checklist. It follows that this error deserves to be coded as a checklist error. It is easy to see how different mishap investigators could possibly code the exact same error as two different nanocodes. This illustrates the issue of reliability at the nanocode level found by O'Connor (2008).

One consequence of the poor reliability at the nanocode level is that the same basic error type is split between two fine-grained nanocodes. This splitting reduces the apparent rate of occurrence between nanocodes. The dilution of this error across two nanocodes may cause it to not draw the attention it deserves. One technique to minimize this reliability concern is to examine the data at the category level. Although the categories lack the fine details of the nanocodes, as discussed in the earlier chapter, they do include groups of similar types of human error. Additionally, the higher occurrence rates at the category level have been shown to exhibit acceptable reliability in the coding process (Wiegmann & Shappell, 2001, 2003).

Another problem with focusing exclusively on nanocodes is that in the nine years of mishap data available, not all of the 147 nanocodes were utilized. In fact, 37 nanocodes have yet to be cited in any Navy or Marine Corps mishap (e.g., PC510 incapacitating spatial disorientation, SP005 proficiency, etc.) At the other end of the spectrum, only 25 nanocodes have been cited in 10 or more of the 141 mishaps. This disparity in distribution is troublesome for many statistical techniques that rely on the assumptions that causal factors are independent of each other and occur with uniform frequency. From the evidence above, it is clear nanocode errors do not occur with a uniform distribution of frequency.

There is also not any evidence to suggest that the underlying errors of nanocodes are independent of each other. Recall the scenario wherein a pilot who is stressed about an upcoming performance review from a commanding officer with whom he doesn't get along. Assume for the moment that the stressed pilot makes a checklist error and forgets to lower the landing gear on final approach. The individual nanocodes of "AE102 Checklist Error," "PC204

Emotional State," and "SI005 Personality Conflict" may be cited in the resulting mishap investigation. It is hard to see these errors as independent events, because they describe a chain of events that led up to the mishap. In fact, this is the very "Domino theory" on which DoD-HFACS is based.

A Monte Carlo simulation based on a Poisson distribution was considered as a means of comparing the occurrence rates of individual DoD-HFACS categories between communities and services. As an example, individual comparisons of each of the 20 categories between Navy and Marine Corps F/A-18s by simulation, while tedious, could determine if different occurrence rates are statistically significant. Although possibly interesting from a statistician's point of view, safety professionals with limited resources are interested in addressing the most pressing issues. While it may be true that communication and coordination errors occur statistically more often in helicopters in the Marine Corps than in the Navy, the usefulness of this information for prevention is minimal. What is most useful to the Naval Safety Center is the fact that it is the number one error in both communities. This is actionable information that leaders can use in making decisions about safety programs and the allocation of limited resources.

For the reasons outlined above, the focus of this analytic effort will be to show the occurrence rates of DoD-HFACS levels, categories, and nanocodes in rank order and compare them for similar communities across the two services. In this way, safety professionals will be able to quickly deduce the areas most in need of attention and determine if those areas are the same for the Navy and the Marine Corps. To illustrate, it is possible that Navy F/A-18 mishaps may result from different reasons than is the case in the Marine Corps. These differences may represent an interesting phenomenon for further investigation. Differences in mission, culture, and operating environment may be the cause, but perhaps there are lessons that can be shared between the services that would lower both mishap rates.

E. RESULTS

In order to analyze the data in a way to be useful to safety professionals in the Naval Aviation community, a series of Pareto charts and tables will be presented for each community of interest. Pareto charts are used to display the order and relative differences between many categories of data. The Pareto charts will display the DoD-HFACS levels, categories, and nanocodes organized by rate per 100,000 flight hours to highlight the most prevalent factors. Communities that will be examined are:

1. Navy and Marine Corps Combined (F/A-18, AV-8B, H-60, H-53, H-46, UH-1, & AH-1W)
2. Overall Navy (F/A-18 & H-60)
3. Overall Marine Corps (F/A-18, AV-8B, H-53, H-46, UH-1, & AH-1W)
4. Navy F/A-18
5. Marine Corps F/A-18
6. Navy Helicopter (H-60)
7. Marine Corps Helicopter (H-53, H-46, UH-1, & AH-1W)

For each community a summary table will list basic information such as number of mishaps and flight hours between FY2000 and FY2008, mishap rate per 100,000 fight hours, total number of DoD-HFACS nanocodes cited, nanocode rate per 100,000 flight hours, and a list of the top five DoD-HFACS categories by frequency rate. Also included are the percentages of total errors that are captured by the top five categories and top twenty nanocodes. These figures indicate the percentage of the total number of human errors represented by these top-occurring error types. Pareto style charts will illustrate the rate of occurrence of DoD-HFACS levels, categories and nanocodes. Due to the large number of possible nanocodes, only the twenty most frequently occurring are displayed. The Pareto charts for categories and nanocodes also have comparison data for the corresponding community in the other service. For example, the Navy F/A-18 Top 20 DoD-HFACS Nanocode Pareto chart (Figure 23) lists the top twenty occurring nanocodes. The top five nanocodes are highlighted for clarity. Additionally, the top five nanocodes for Marine Corps F/A-18s are highlighted in red and labeled one through five. In this particular case, the number five Marine Corps nanocode does not appear in the Navy's top 20 list. It is listed inside the red box. Using these Pareto charts, a quick comparison is possible between similar communities in the Navy and Marine Corps.

1. Navy and Marine Corps Combined (F/A-18, AV-8B, H-60, H-53, H-46, UH-1, & AH-1W)

The Navy and Marine Corps combined dataset represents all mishaps between FY2000 and FY2008 for which DoD-HFACS nanocodes are available. It should be noted that as discussed earlier, not all aircraft operated by the services during this time period are represented in this data. Only the platforms listed above have had their mishap reports coded into DoD-HFACS. Table 2 summarizes the data and lists coordination/communication/planning factors as the number one category. Figure 12 identifies preconditions as being the level where most errors occur. Figure 13 illustrates that coordination/communication/ planning factors and skill-based errors are clearly the two leading DoD-HFACS categories, each occurring at twice the rate of the third leading cause, psycho-behavioral factors. Three skill-based error nanocodes: procedural error, over/ undercontrol, and breakdown in scan are listed among the top five nanocodes in Figure 14.

Table 2. Navy and Marine Corps Combined DoD-HFACS Summary Table

Mishaps	141	**Top 5 DoD-HFACS Categories**	
Flight Hours	5,607,687	**1.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Mishap Rate	2.51	**2.**	SKILL-BASED ERRORS
Nanocodes	831	**3.**	PSYCHO-BEHAVIORAL FACTORS
Nanocode Rate	14.82	**4.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 5 categories	60.6%	**5.**	AWARENESS (COGNITIVE) FACTORS
Percentage of nanocodes accounted for in top 20 nanocodes	60.9%		

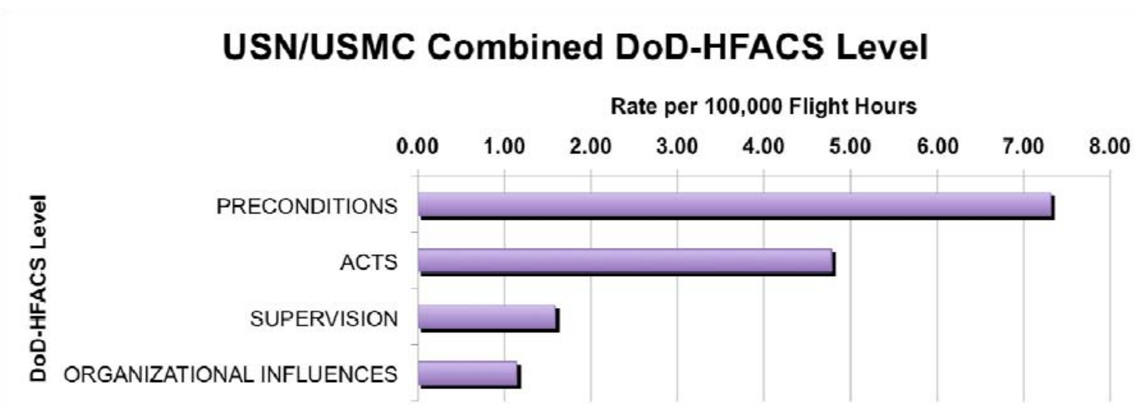

Figure 12. Navy and Marine Corps Combined DoD-HFACS Level Rates

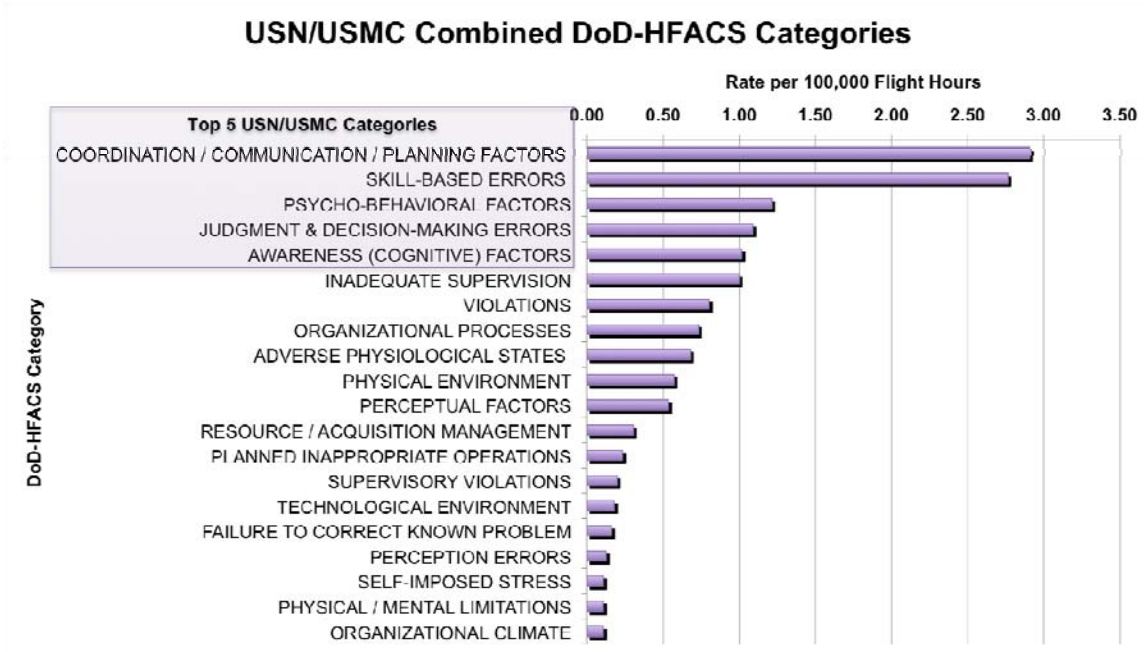

Figure 13. Navy and Marine Corps Combined DoD-HFACS Category Rates

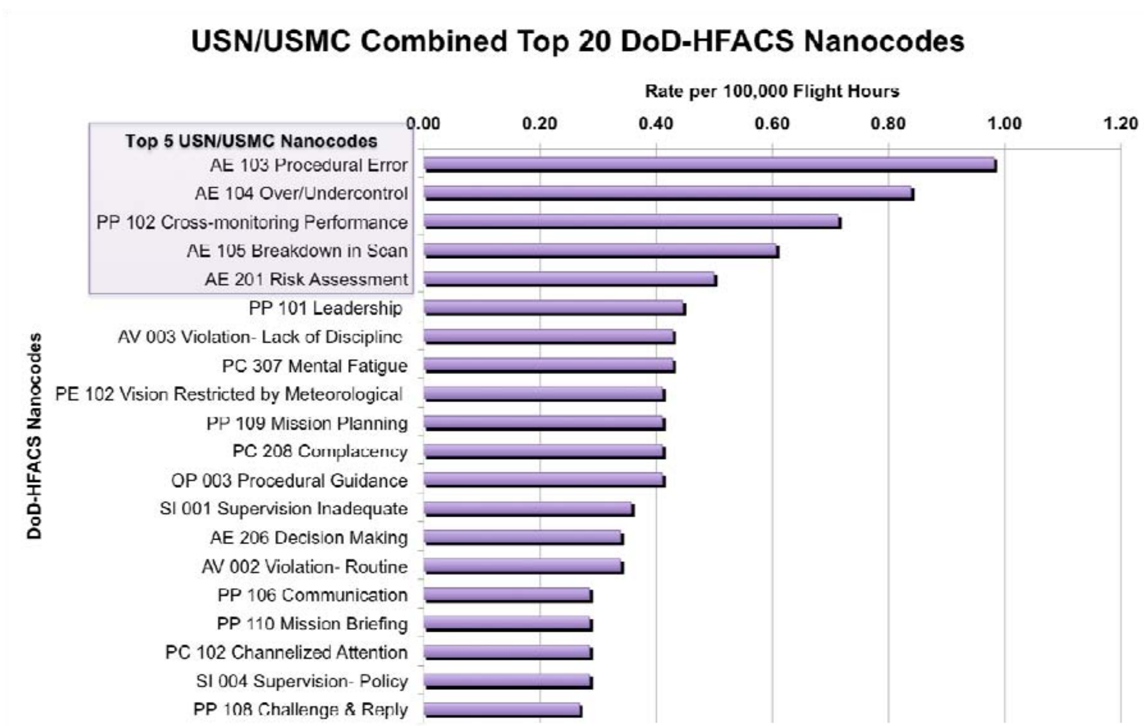

Figure 14. Navy and Marine Corps Combined Top 20 DoD-HFACS Nanocode Rates

2. Overall Navy (F/A-18 & H-60)

The overall Navy dataset contains the only two Navy platforms for which DoD-HFACS nanocode data exists: the F/A-18 and the H-60. Table 3 summarizes the data and lists skill-based errors as the number one category. Figure 15 identifies preconditions as being the level where most errors occur. Figure 16 illustrates that skill-based errors and coordination/communication planning factors are not only the top two categories in the Navy, but in the Marine Corps as well. In fact, the top seven Navy categories include the top five Marine Corps categories. At the nanocode level, the two services share three of the top five nanocodes: procedural error, over/undercontrol, and breakdown in scan (see Figure 17).

Table 3. Overall Navy DoD-HFACS Summary Table

Mishaps	63	**Top 5 DoD-HFACS Categories**	
Flight Hours	2,988,101	**1.**	SKILL-BASED ERRORS
Mishap Rate	2.11	**2.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Nanocodes	361	**3.**	INADEQUATE SUPERVISION
Nanocode Rate	12.08	**4.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 5 categories	62.0%	**5.**	AWARENESS (COGNITIVE) FACTORS
Percentage of nanocodes accounted for in top 20 nanocodes	63.2%		

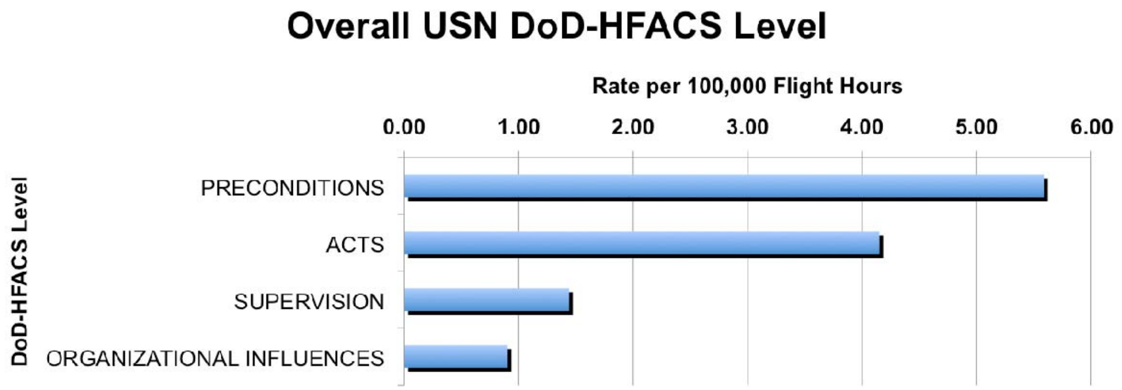

Figure 15. Overall Navy DoD-HFACS Level Rates

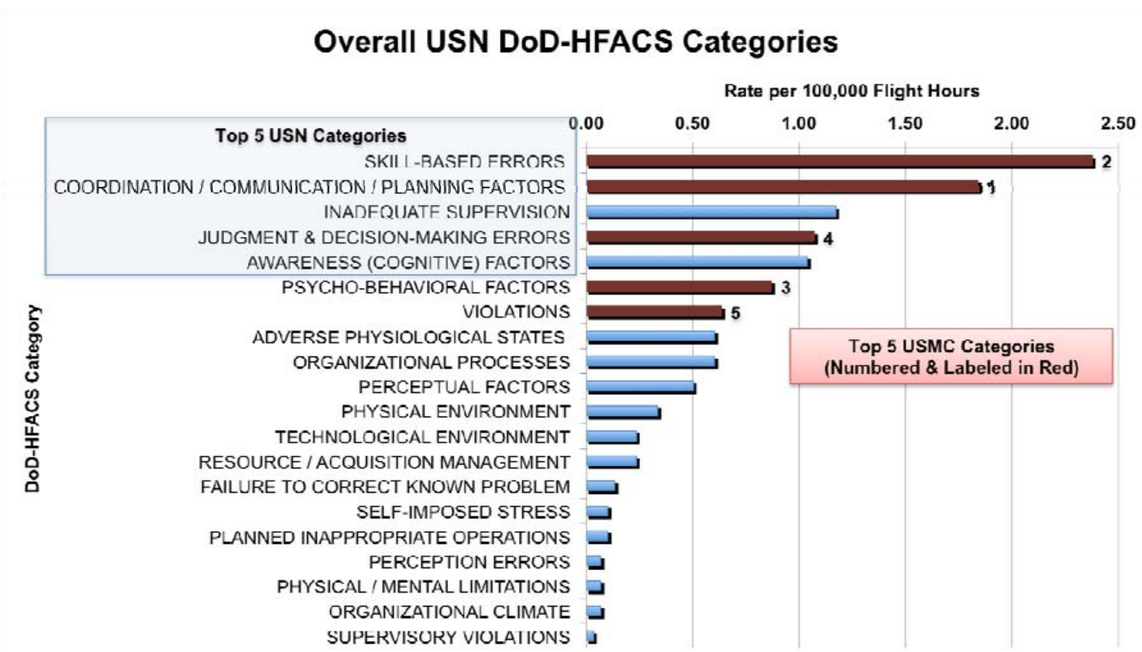

Figure 16. Overall Navy DoD-HFACS Category Rates

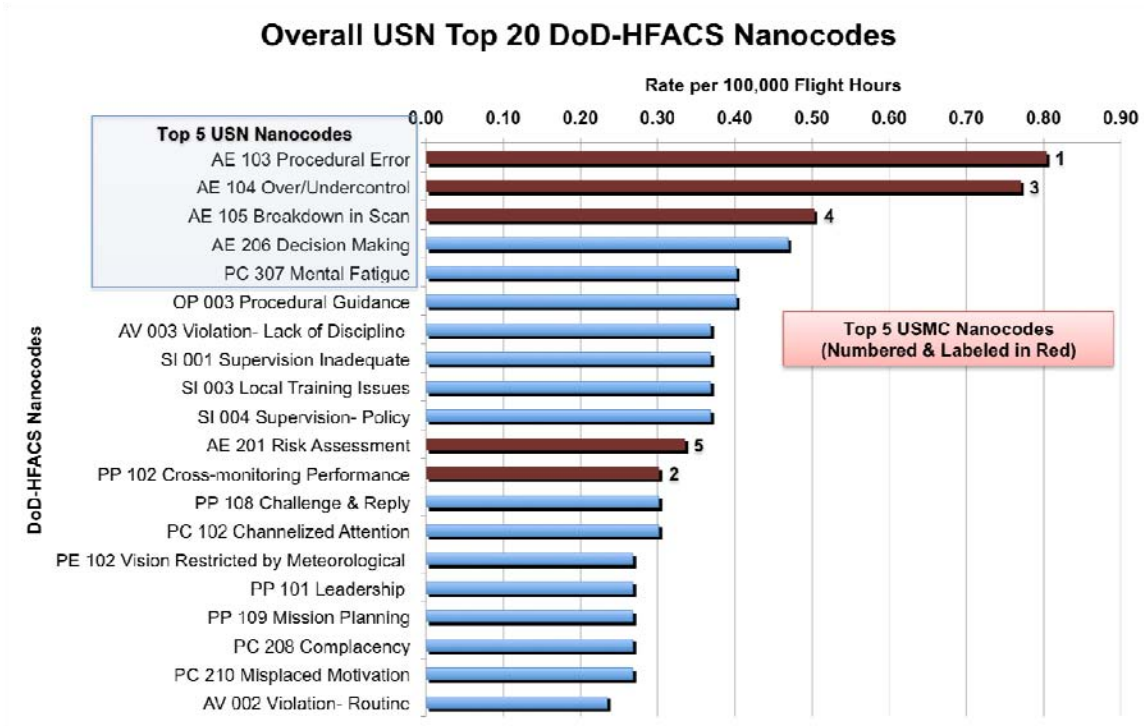

Figure 17. Overall Navy Top 20 DoD-HFACS Nanocode Rates

3. Overall Marine Corps (F/A-18, AV-8B, H-53, H-46, UH-1, & AH-1W)

The overall Marine Corps dataset contains two strike/fighter platforms (F/A-18 and AV-8B) and four helicopters (H-53, H-46, UH-1, & AH-1W). Table 4 summarizes the data and lists coordination/communication/planning factors as the number one category. Figure 18 identifies preconditions as being the level where most errors occur. Figure 19 illustrates that while three of the top five categories are shared with the Navy, two categories are not: psycho-behavioral factors and violations. As previously mentioned, the two services share three of the top five nanocodes: procedural error, over/undercontrol, and breakdown in scan. However, one nanocode in the Navy's top five, decision making, does not appear in the Marine Corps' top 20. (see Figure 20).

Table 4. Overall Marine Corps DoD-HFACS Summary Table

Mishaps	78	**Top 5 DoD-HFACS Categories**	
Flight Hours	2,619,586	**1.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Mishap Rate	2.98	**2.**	SKILL-BASED ERRORS
Nanocodes	470	**3.**	PSYCHO-BEHAVIORAL FACTORS
Nanocode Rate	17.94	**4.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 5 categories	61.5%	**5.**	VIOLATIONS
Percentage of nanocodes accounted for in top 20 nanocodes	61.7%		

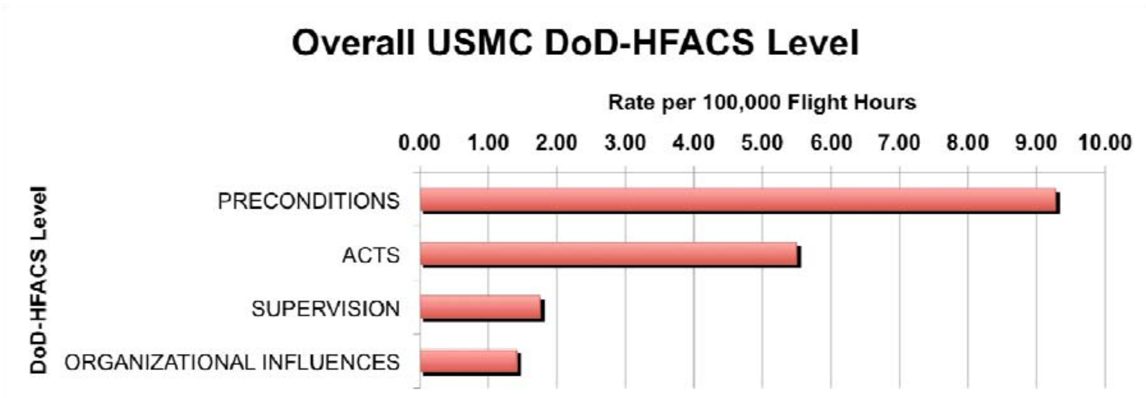

Figure 18. Overall Marine Corps DoD-HFACS Level Rates

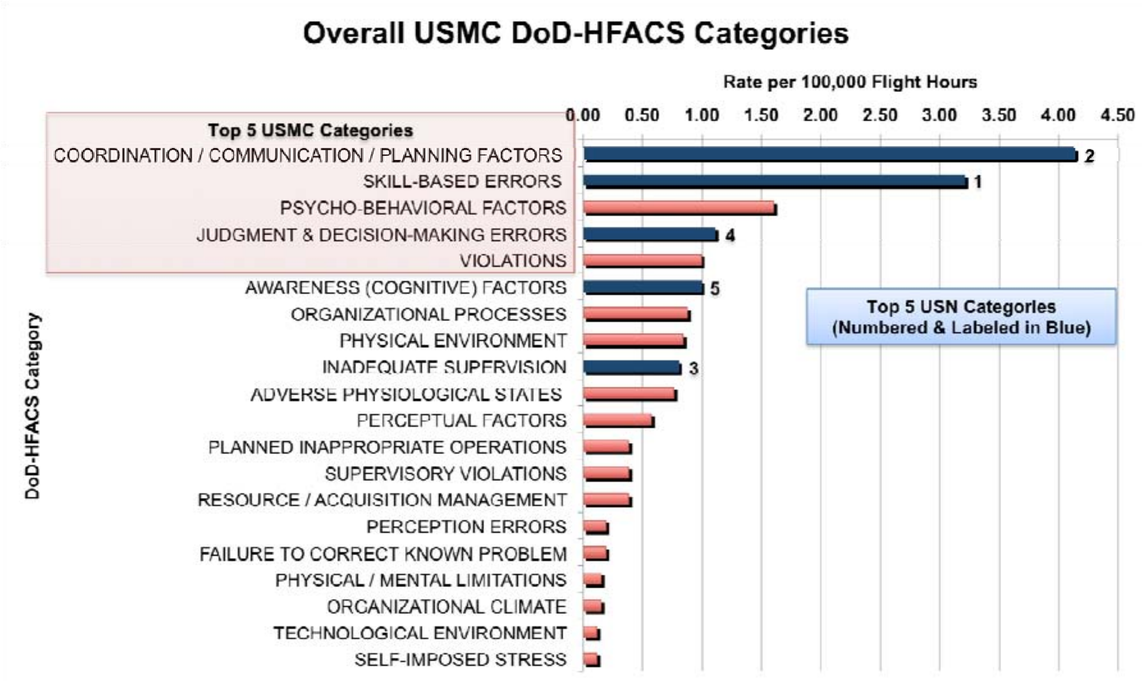

Figure 19. Overall Marine Corps DoD-HFACS Category Rates

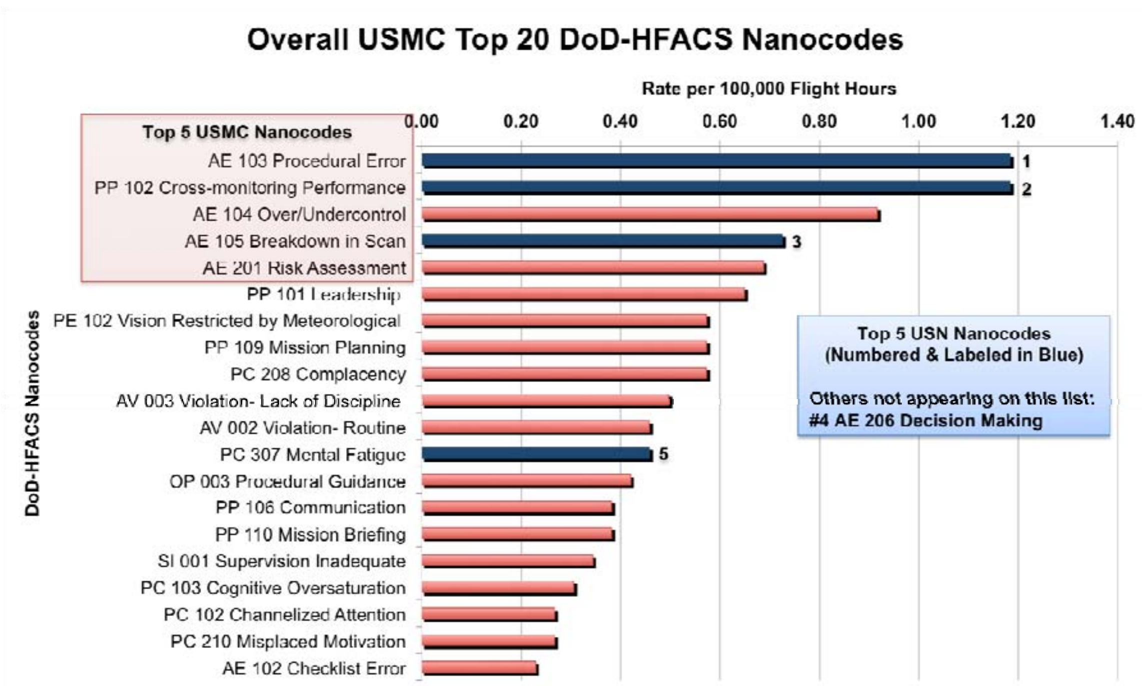

Figure 20. Overall Marine Corps Top 20 DoD-HFACS Nanocode Rates

4. Navy F/A-18

The Navy F/A-18 dataset contains all single and two-seat variants of the Hornet and Super Hornet. Table 5 summarizes the data and lists skill-based errors as the number one category. Figure 21 identifies preconditions as being the level where most errors occur. Figure 22 illustrates that skill-based errors and coordination/communication/planning factors are the top two categories in both the Navy and Marine Corps F/A-18 communities. At the nanocode level (shown in Figure 23), three skill-based errors (procedural error, over/undercontrol, and breakdown in scan) are common to both services' F/A-18 top five list, while cross-monitoring performance, a Marine Corps top five category, does not appear on the Navy's top 20 list.

Table 5. Navy F/A-18 DoD-HFACS Summary Table

Mishaps	47	**Top 5 DoD-HFACS Categories**	
Flight Hours	1,823,327	**1.**	SKILL-BASED ERRORS
Mishap Rate	2.58	**2.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Nanocodes	227	**3.**	AWARENESS (COGNITIVE) FACTORS
Nanocode Rate	12.45	**4.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 5 categories	61.2%	**5.**	INADEQUATE SUPERVISION
Percentage of nanocodes accounted for in top 20 nanocodes	65.6%		

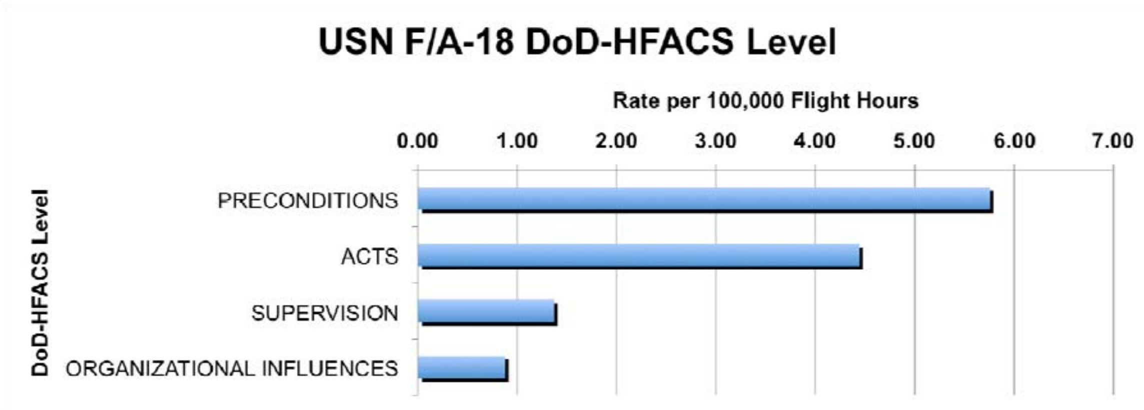

Figure 21. Navy F/A-18 DoD-HFACS Level Rates

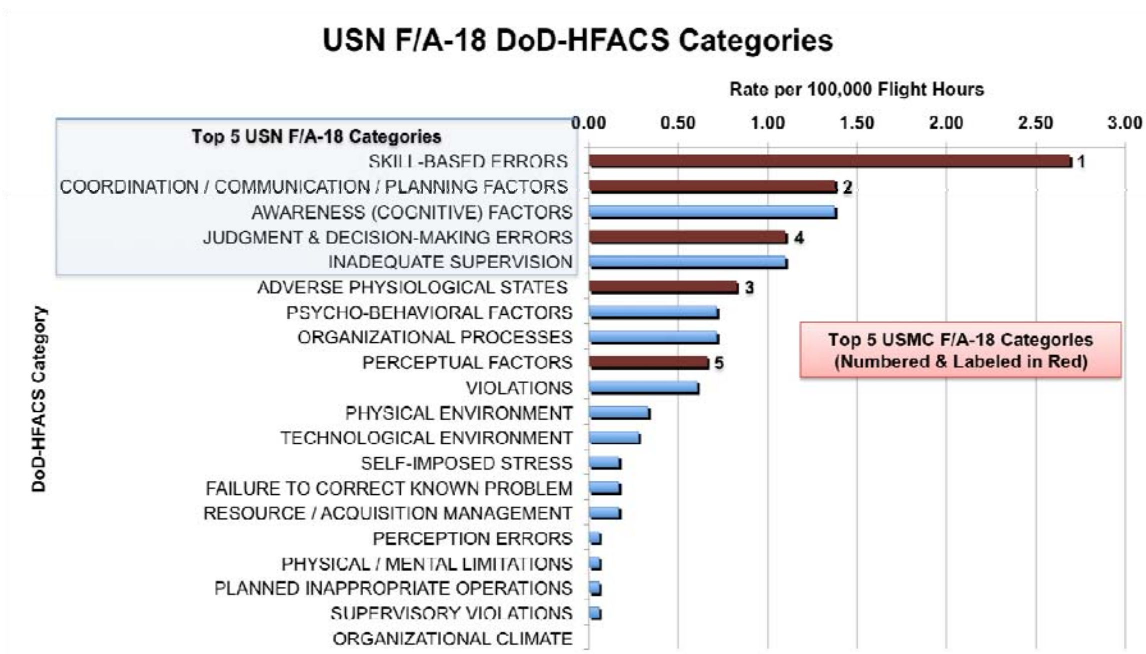

Figure 22. Navy F/A-18 DoD-HFACS Category Rates

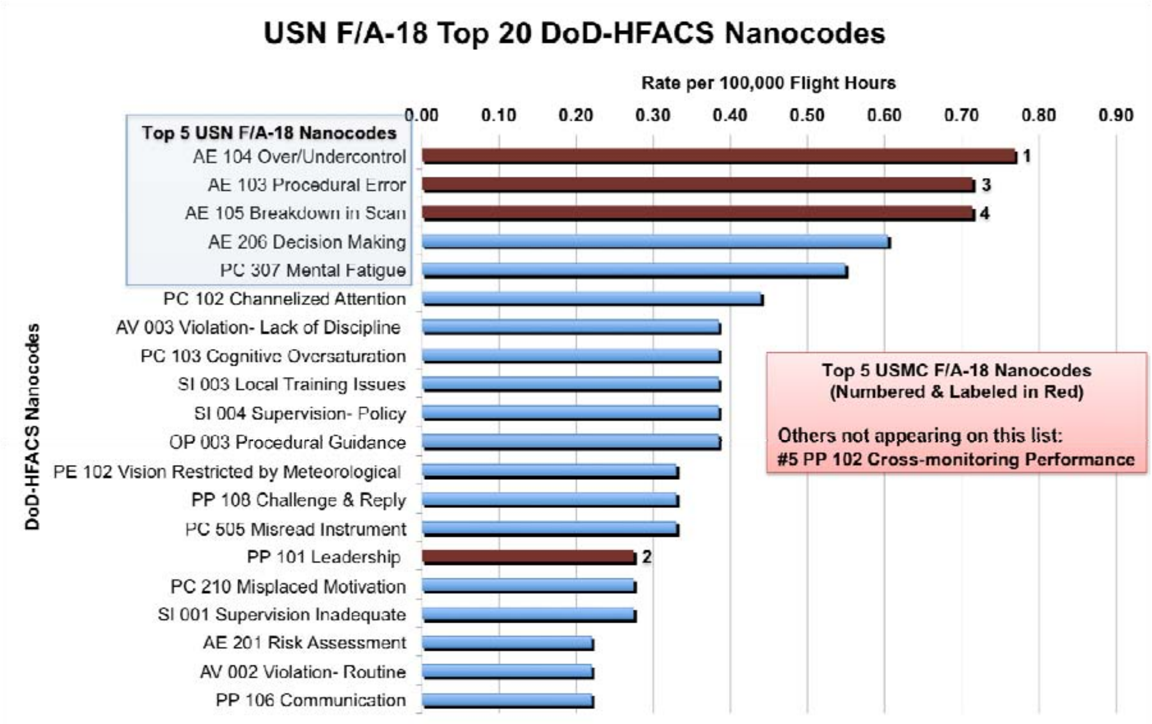

Figure 23. Navy F/A-18 Top 20 DoD-HFACS Nanocode Rates

5. Marine Corps F/A-18

The Marine Corps F/A-18 dataset contains all single and two-seat variants of the Hornet; the Marine Corps does not fly the Super Hornet. Table 6 summarizes the data with skill-based errors identified as the number one category. Figure 24 identifies preconditions as being the level where most errors occur. Figure 25 again illustrates that skill-based errors and coordination/communication/planning factors are the top two categories in both the Navy and Marine Corps F/A-18 communities. Figure 25 also shows that five categories: perception error, physical environment, physical/mental limitations, psycho-behavioral factors, and supervisory violations have yet to be cited in any Marine Corps F/A-18 mishaps. Although three nanocodes (procedural error, over/undercontrol, and breakdown in scan) are in the top five of both Navy and

Marine Corps F/A-18s, two of the Navy's top five (decision making and mental fatigue) are either at the bottom or do not make the Marine Corps' top 20 list (see Figure 26).

Table 6. Marine Corps F/A-18 DoD-HFACS Summary Table

Mishaps	23	**Top 5 DoD-HFACS Categories**	
Flight Hours	814,914	**1.**	SKILL-BASED ERRORS
Mishap Rate	2.82	**2.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Nanocodes	62	**3.**	ADVERSE PHYSIOLOGICAL STATES
Nanocode Rate	7.61	**4.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 5 categories	72.6%	**5.**	PERCEPTUAL FACTORS
Percentage of nanocodes accounted for in top 20 nanocodes	75.8%		

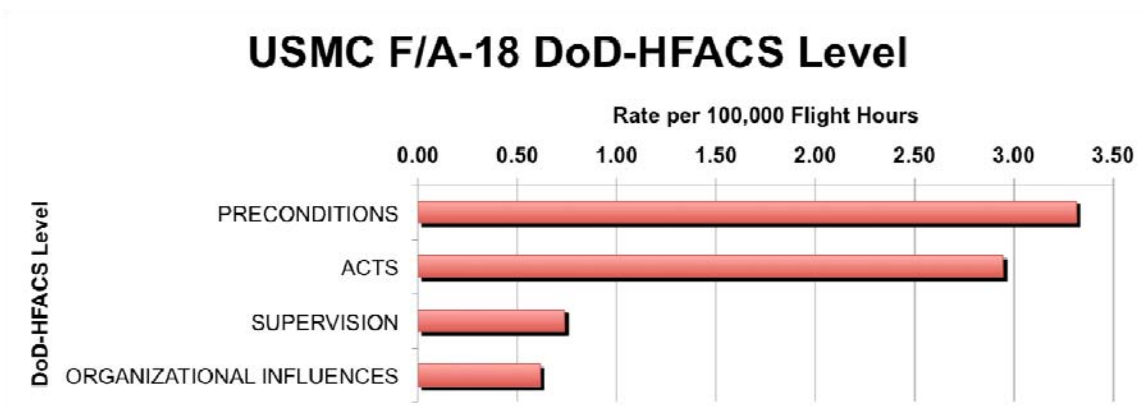

Figure 24. Marine Corps F/A-18 DoD-HFACS Level Rates

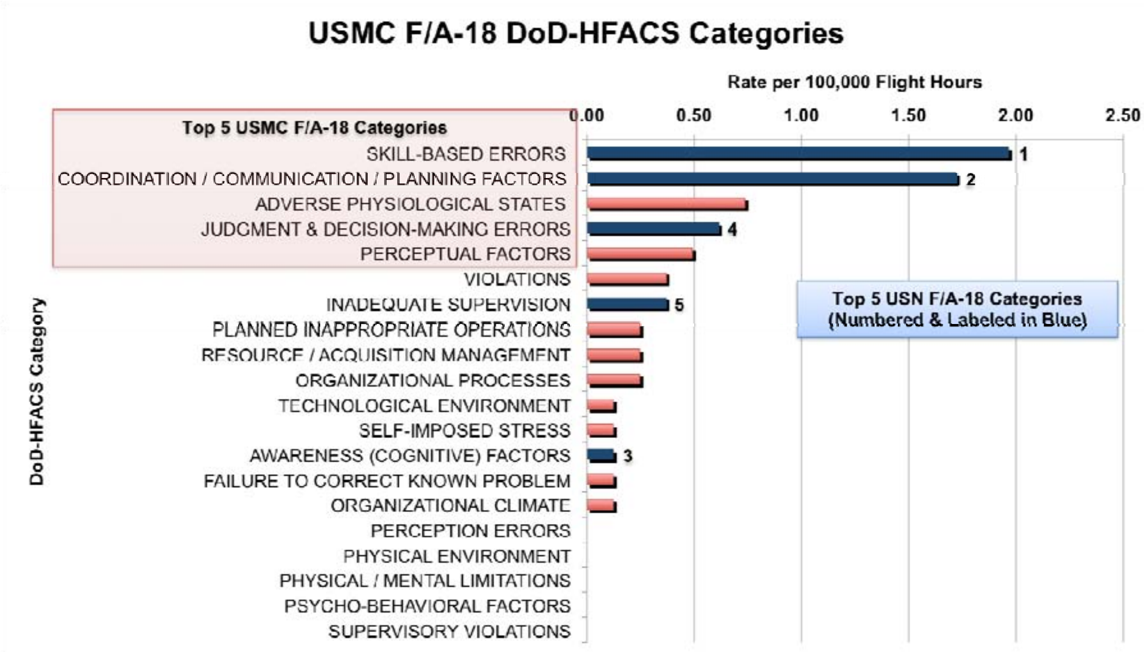

Figure 25. Marine Corps F/A-18 DoD-HFACS Category Rates

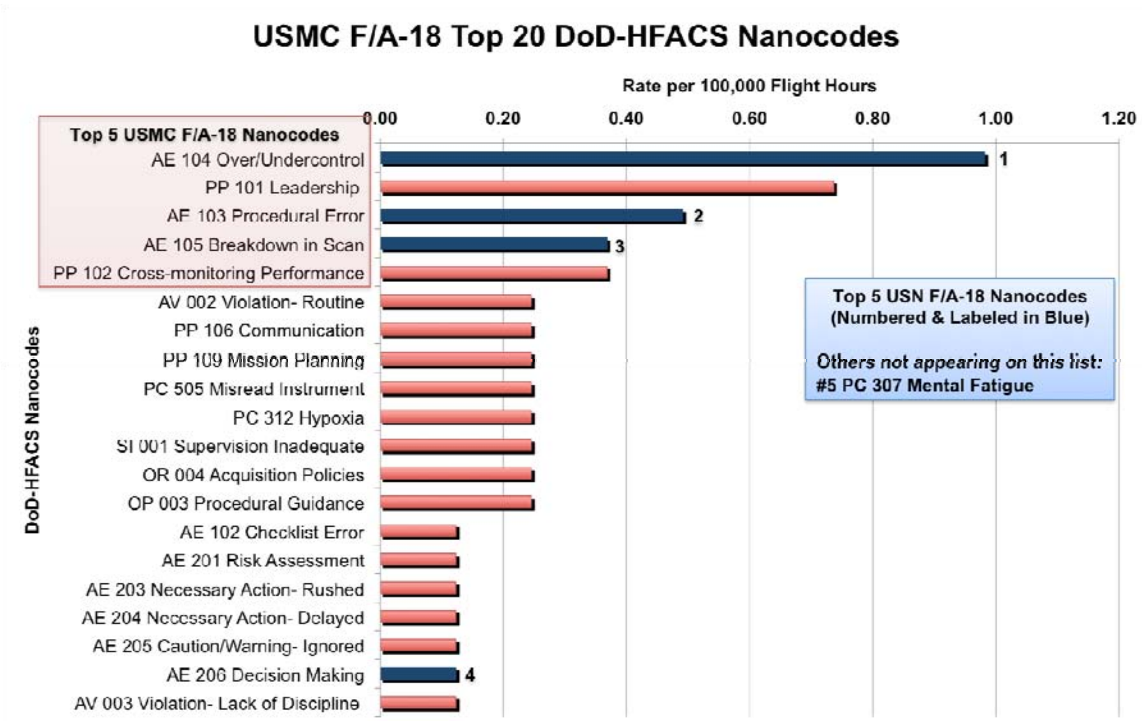

Figure 26. Marine Corps F/A-18 Top 20 DoD-HFACS Nanocode Rates

6. Navy Helicopter (H-60)

The Navy helicopter dataset contains all variants of the H-60 Seahawk. Table 7 summarizes the data and lists coordination/communication/planning factors as the number one category. Figure 27 identifies preconditions as being the level where most errors occur. Figure 28 illustrates that coordination/communication/planning factors, skill-based errors, and psycho-behavioral factors are three categories in the top five of both the Navy and Marine Corps helicopter communities. Additionally, the Marine Corps' fourth most frequent category, violations, ranked sixth in the Navy. Three of the top five nanocodes in Navy helicopters were common to the Marine Corps: procedural error, risk assessment, and cross-monitoring performance (see Figure 29).

Table 7. Navy Helicopter DoD-HFACS Summary Table

Mishaps	16	**Top 5 DoD-HFACS Categories**	
Flight Hours	1,164,774	**1.**	COORDINATION/ COMMUNICATION PLANNING FACTORS
Mishap Rate	1.37	**2.**	SKILL-BASED ERRORS
Nanocodes	134	**3.**	INADEQUATE SUPERVISION
Nanocode Rate	11.50	**4.**	PSYCHO-BEHAVIORAL FACTORS
Percentage of nanocodes accounted for in top 5 categories	68.7%	**5.**	JUDGMENT & DECISION-MAKING ERRORS
Percentage of nanocodes accounted for in top 20 nanocodes	68.7%		

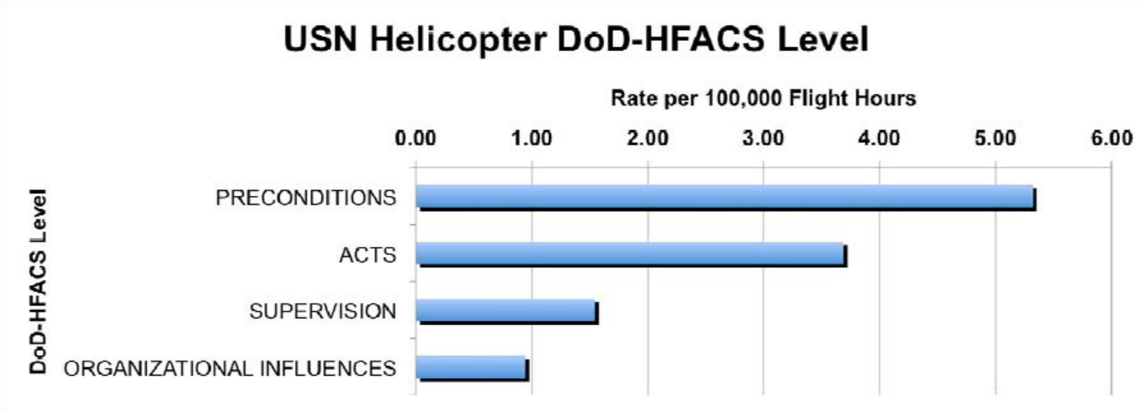

Figure 27. Navy Helicopter DoD-HFACS Level Rates

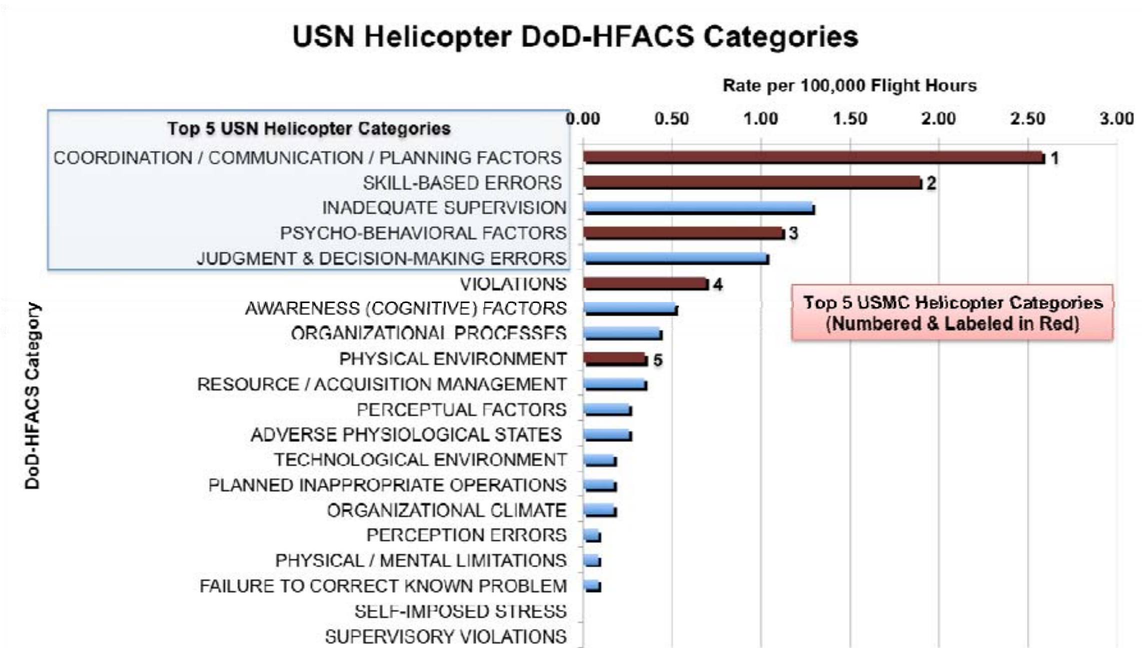

Figure 28. Navy Helicopter DoD-HFACS Category Rates

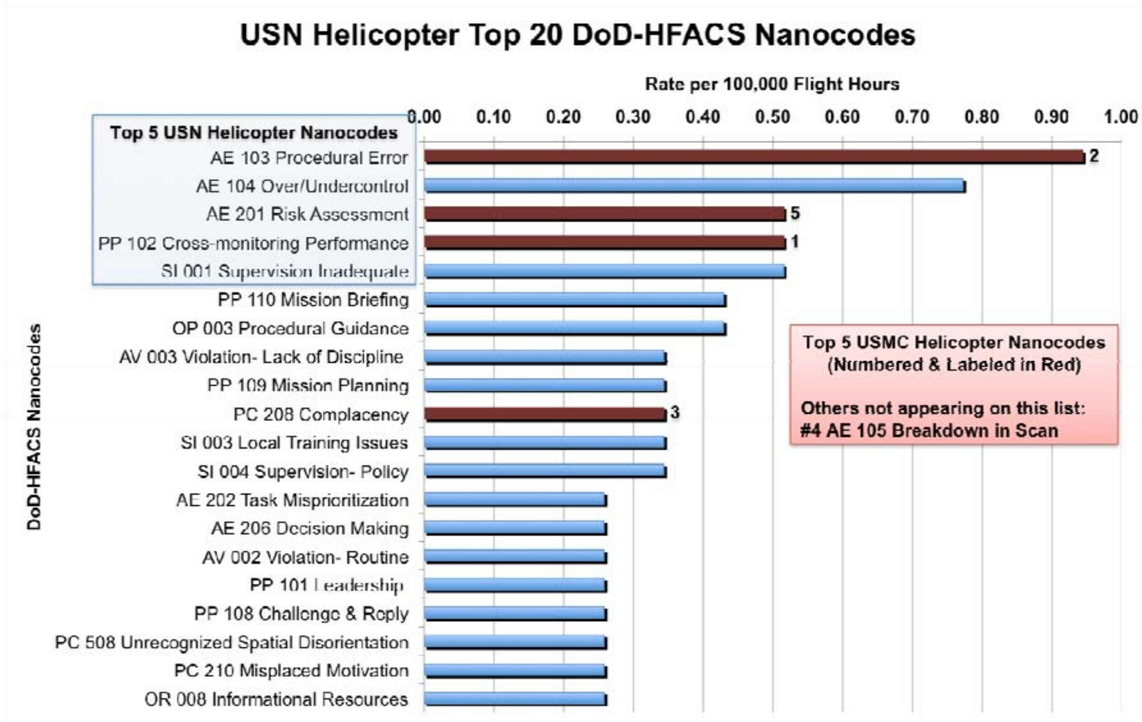

Figure 29. Navy Helicopter Top 20 DoD-HFACS Nanocode Rates

7. Marine Corps Helicopter (H-53, H-46, UH-1, & AH-1W)

The Marine Corps helicopter dataset contains all variants of four helicopters: the H-53, the H-46, the UH-1, and the AH-1W. Table 8 summarizes the data and lists coordination/communication/planning factors as the number one category. Figure 30 identifies preconditions as being the level where most errors occur. Figure 31 reaffirms that that coordination/communication/planning factors, skill-based errors, and psycho-behavioral factors are three categories in the top five of both the Navy and Marine Corps helicopter communities. Additionally, the Navy's remaining two top five categories, inadequate supervision and judgment and decision-making errors, rank sixth and seventh on the Marine Corps' list. Once again, Figure 32 shows that three of the top five nanocodes (procedural error, risk assessment, and cross-monitoring performance) are shared by Navy and Marine Corps helicopters. One of Navy's top five nanocodes, supervision inadequate, did not appear of the Marine Corps' top 20 list.

Table 8. Marine Corps Helicopter DoD-HFACS Summary Table

Mishaps	31	**Top 5 DoD-HFACS Categories**	
Flight Hours	1,483,029	**1.**	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
Mishap Rate	2.09	**2.**	SKILL-BASED ERRORS
Nanocodes	279	**3.**	PSYCHO-BEHAVIORAL FACTORS
Nanocode Rate	18.81	**4.**	VIOLATIONS
Percentage of nanocodes accounted for in top 5 categories	64.2%	**5.**	PHYSICAL ENVIRONMENT
Percentage of nanocodes accounted for in top 20 nanocodes	64.5%		

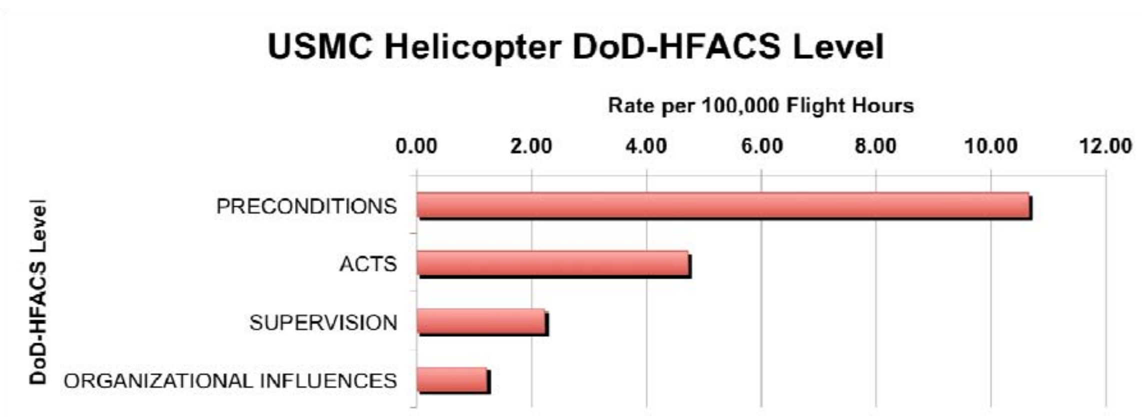

Figure 30. Marine Corps Helicopter DoD-HFACS Level Rates

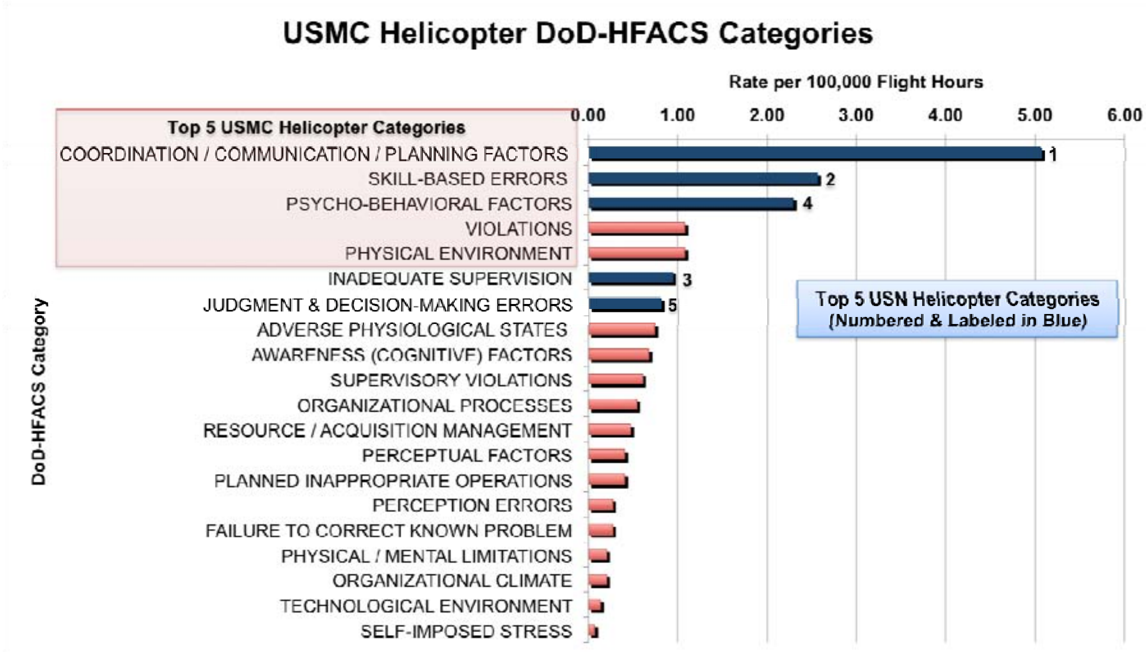

Figure 31. Marine Corps Helicopter DoD-HFACS Category Rates

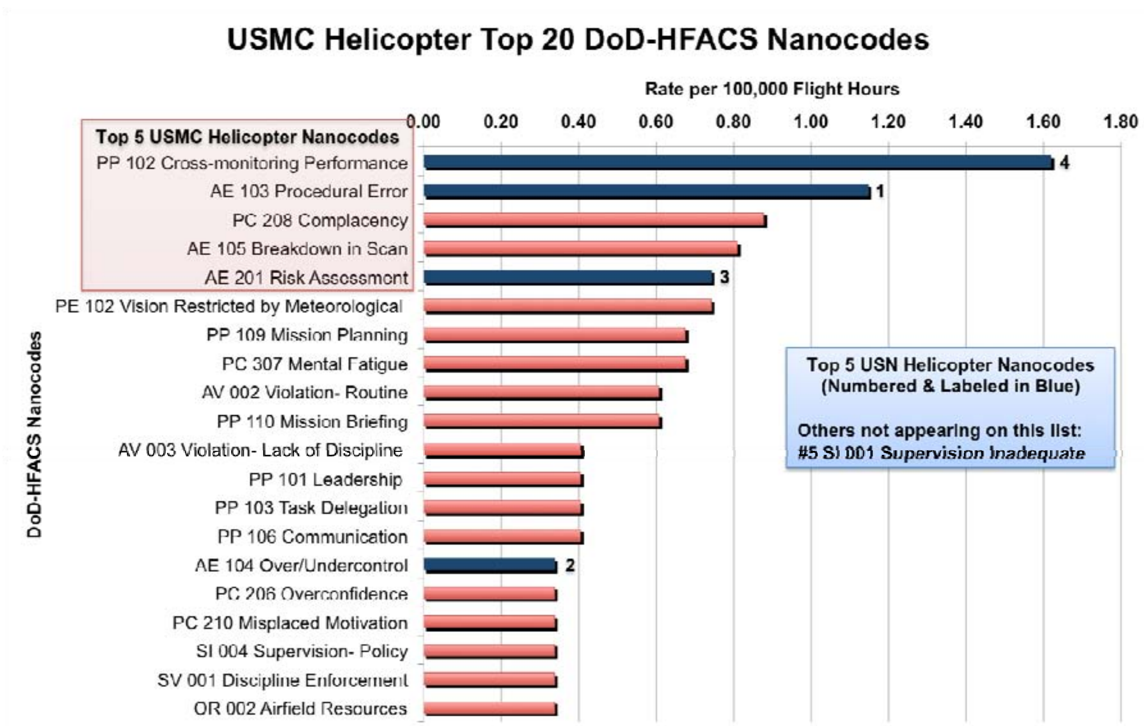

Figure 32. Marine Corps Helicopter Top 20 DoD-HFACS Nanocode Rates

F. DISCUSSION

The primary objective of this analytical effort was to identify which DoD-HFACS categories were most commonly used to classify mishaps within various subgroups within Naval Aviation. Table 9 summarizes the five most frequently occurring DoD-HFACS categories. The top two categories across all communities were skill-based errors and coordination/communication/planning factors. In general, these two categories occurred at a much higher rate than other categories, doubling the occurrence rate of the third place category in many cases. Judgment and decision-making errors appeared in the top five list of all but Marine Corps helicopters, where it placed seventh. From this analysis it is clear that safety efforts should focus on these areas.

Table 9. Summary Table of Top Five DoD-HFACS Categories

ALL	USN	USMC	USN F/A-18	USMC F/A-18	USN Helicopter	USMC Helicopter
COORDINATION/ COMMUNICATION/ PLANNING FACTORS	SKILL-BASED ERRORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS	SKILL-BASED ERRORS	SKILL-BASED ERRORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS
SKILL-BASED ERRORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS	SKILL-BASED ERRORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS	COORDINATION/ COMMUNICATION/ PLANNING FACTORS	SKILL-BASED ERRORS	SKILL-BASED ERRORS
PSYCHO-BEHAVIORAL FACTORS	INADEQUATE SUPERVISION	PSYCHO-BEHAVIORAL FACTORS	AWARENESS (COGNITIVE) FACTORS	ADVERSE PHYSIOLOGICAL STATES	INADEQUATE SUPERVISION	PSYCHO-BEHAVIORAL FACTORS
JUDGMENT & DECISION-MAKING ERRORS	JUDGMENT & DECISION-MAKING ERRORS	JUDGMENT & DECISION-MAKING ERRORS	JUDGMENT & DECISION-MAKING ERRORS	JUDGMENT & DECISION-MAKING ERRORS	PSYCHO-BEHAVIORAL FACTORS	VIOLATIONS
AWARENESS (COGNITIVE) FACTORS	AWARENESS (COGNITIVE) FACTORS	VIOLATIONS	INADEQUATE SUPERVISION	PERCEPTUAL FACTORS	JUDGMENT & DECISION-MAKING ERRORS	PHYSICAL ENVIRONMENT

Moving up the DoD-HFACS hierarchy to examine the frequency of levels identified in mishaps, the order was the same in every case: preconditions, acts, supervision, and organizational influences. At first, this might seem surprising given that three of the top five nanocodes in each community belong to the acts level. The reason that the preconditions level was the most frequently occurring level is likely due to the additive effect of being comprised of 92 nanocodes. In contrast, the acts levels contains just 16 nanocodes. In any case, the levels of DoD-HFACS contain several types of human error that lend themselves to different intervention strategies. Therefore, the relative frequency of the levels of DoD-HFACS provides little insight into the causes and remedies of mishaps.

Turning to the nanocode level, the most common nanocodes were procedural error, over/undercontrol, and breakdown in scan, which are skill-based errors. The most common coordination/communication/planning factors nanocodes were cross-monitoring performance and leadership. Other frequently used nanocodes in the coordination/communication/planning factors category include: mission planning, mission briefing, communication, and challenge and reply. Although these nanocodes occurred at different frequencies within specific communities, they describe specific errors that generalize to the aviation community as a whole.

Although intervention strategy generation will be discussed in more depth in Chapter V, the results of this analytic effort appear to support the reasoning behind traditional safety programs. Procedural and proficiency training have long been a hallmark of Naval Aviation. These efforts clearly are aimed at reducing the frequency of skill-based errors. Another prominent safety program within Naval Aviation is Crew Resource Management (CRM). CRM is specifically designed to improve the coordination and communication between aircrew and reduce the error types within the coordination/communication/planning factors category. To examine the relevance of these results to mishaps outside Naval Aviation, these findings will be compared to other aviation studies that have used HFACS to classify mishap causal factors.

1. Comparison with Other HFACS Studies

Comparing these results to previous studies of military aviation mishaps revealed many similarities. Gibb and Olson (2008) examined 124 U.S. Air Force class A mishaps between October 1992 and March 2005 that were classified into one of four types: controlled flight into terrain (CFIT), loss of control (LoC), spatial disorientation (SD), or midair collision (Midair). The CFIT category was further subdivided into mishaps that occurred during the enroute portion of flight (CFIT-

1) and in the approach and landing phase of flight (CFIT-2/ALA). In this study mishap reports were recoded from the original format into HFACS and frequencies at each level were determined by mishap type. Table 10 summarizes their findings. The top five DoD-HFACS categories of all Navy and Marine Corps mishaps from the current analytical effort are also found on Gibb and Olson's list of most frequent mishap categories. This suggests that human error types in the U.S. Air Force are similar to those found in the Navy and Marine Corps.

Table 10. Summary of Most Frequent HFACS Categories Contributing to a Mishap Sequence (From: Gibb & Olson, 2008, p. 318)

	HFACS Category		
	Supervision (Latent)	*Precondition (Latent)*	*Act*
CFIT-1	Risk Proficiency	CCP:[a] Mission Planning	J/DM: Risk DM
CFIT-2/ALA	Proficiency Experience	CCP:[a] Monitoring	J/DM: Risk DM
LoC	Proficiency	Psychobehavioral[a] Over-Confd/Aggress Complacency	SB: Procedure Ov/Un Cont
SD	Experience Proficiency	Perceptual[a] SD	J/DM: Task MP Perception
Midair	Proficiency Experience	Cognitive: ChnAt	SB: Visual scan

Note. CFIT = controlled flight into terrain; ALA = approach and landing accident; LoC = loss of control; SD = spatial disorientation; CCP = coordination, communication, and planning factors; ChnAt = channelized attention; J/DM = judgment/decision making; Over-Confd/Aggress = overconfidence and overaggressive; Ov/Un Cont = over/under control; SB = skill-based; Task MP = task misprioritization.

Three other studies have examined aviation mishaps using the HFACS taxonomy. Li and Harris (2006) examined 523 mishaps that occurred in the Republic of China (R.O.C.) Air Force from 1978 to 2002. Investigation reports were then recoded into the Wiegmann and Shappell HFACS taxonomy. Wiegmann and Shappell (2001) examined U.S. commercial aviation mishaps using HFACS. In that study, 119 mishaps between 1990 and 1996 were also coded from mishap reports using the HFACS taxonomy. Shappell et al.

conducted a follow on study in 2007 of commercial aviation that included a total of 1,020 accidents from 1990 to 2002. Once again, HFACS was used to recode investigation reports for analysis.

Table 11 summarizes the findings from these three studies and compares them to the current analytical effort. Skill-based errors and judgment decision-making errors (called decision errors in the HFACS taxonomy) appeared in the top five categories of all four studies. It is not surprising that these two human error types are consistent across military, civil, and foreign military aviation communities. All mishaps were the direct result of some action. In the HFACS taxonomy, skill-based and decision-making errors comprise the majority of possible actions that can directly cause a mishap. A more compelling issue for safety professionals to examine is the circumstances that encourage the occurrence of these errors.

Table 11. Comparison of Current Analytical Effort to Three Studies of Aviation Error Using HFACS Taxonomy

HFACS Category Rank Order	U.S. Navy & Marine Corps 2000-2008 (Cowan, 2009)	R.O.C. Air Force 1978-2002 (After: Li & Harris, 2006)	U.S. Commercial Aviation 1990-1996 (After: Wiegmann & Shappell, 2001)	U.S. Commercial Aviation 1990-2002 (After: Shappell et al., 2007)
1	Coordination/ Communication/ Planning Factors	Skill-Based Errors	Skill-Based Errors	Physical Environment
2	Skill-Based Errors	Decision Errors	Crew Resource Management	Skill-Based Errors
3	Psycho-Behavioral Factors	Adverse Mental States	Decision Errors	Decision Errors
4	Judgment & Decision-Making Errors	Resource Management	Violations	Violations
5	Awareness (Cognitive) Factors	Inadequate Supervision	Perceptual Errors	Crew Resource Management

In the DoD-HFACS taxonomy Awareness (Cognitive) Factors and Psycho-Behavioral Factors are both combined in Adverse Mental States in the version of HFACS used in the studies by Wiegmann and Shappell (2001), Shappell et al. (2007), and Li and Harris (2005).

Coordination/Communication/Planning Factors in DoD-HFACS is equivalent to Crew Resource Management in HFACS.

G. CONCLUSION

The results of this analytical effort indicate that coordination/ communication/planning factors and skill-based errors were the most common errors in the Naval Safety Center mishap database. Furthermore, these findings are similar to those from other aviation communities. Although this effort has examined mishap data exclusively, it is only one side of the story of human error. The next chapter will examine the opinions of operational aircrews about the most likely types of human error. Using the identified mishap causes of the past and the perceived potential causes of future will possibly yield a more complete picture for safety professionals.

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IV. EXAMINATION OF COMMANDER, NAVAL AIR FORCES STRATEGIC HUMAN FACTORS REVIEW

A. BACKGROUND

Although mishap investigations provide an important feedback mechanism to safety professionals, it is not the only one. Mishap investigations start from “ground zero” in an accident and move up the chain of events to determine contributors to the mishap. The Naval Safety Program instruction OPNAV 3750.6R advises mishap investigators to use their best judgment in determining the most likely causes of a mishap. Investigators are invited to ask the question, “Absent this causal factor would there have been a mishap?” (Chief of Naval Operations, 2007, p. 6–28) Inevitably, the burden of proof for mishap investigators leads to the exclusion of more vague factors that contributed to a mishap, but may not have left an evidence trail in an investigation.

A source of insight that may be able to get at more vague mishap contributors is the opinions of aircrew. Those who conduct air operations every day have a unique perspective to contribute. In an inherently risky enterprise such as aviation, aircrews are likely to have issues that they consider to be threats to their safety. These perceived threats are another vital source of information for building a robust safety program.

B. OBJECTIVE

The objective of this analytical effort is to examine the results of the Commander, Naval Air Forces’ strategic human factors review from the spring of 2008. These results are the considered opinions of current fleet aircrews about the nature of risks they face during flight operations. In addition to identifying their top human factor concerns, this effort will compare the results to the mishap data results described in the previous chapter. The goal is to determine if aircrews identify the same human factors that have been cited in mishaps, or if they provide insight into factors that may not be captured in a mishap investigation.

C. DATA COLLECTION

Following a string of ten class A mishaps in the first half of FY2008, Commander, Naval Air Forces (CNAF) conducted a strategic human factors review aimed at reversing this trend. This review directed all squadrons to examine several aspects of their safety program. One facet of the review asked each individual squadron to identify their top five human factors concerns using the nanocodes of the DoD-HFACS classification system. Squadrons were instructed that they could analyze current issues or try to predict the cause of the next mishap. Results from each squadron were compiled at the appropriate type wing that oversees several squadrons of similar aircraft platforms and relayed to CNAF.

Unfortunately, the strategic human factors review was not conducted according to strict research protocols. The actual details of how each squadron determined its top five human factors causes are unknown. No specific guidance was given by CNAF as to the method of collection. Whether the top five concerns were chosen via a survey of the entire squadron’s aircrew or simply reflect the views of the squadron safety officer or commanding officer is unknown. Likewise, there is no information on the familiarity of DoD-HFACS to those squadrons who responded. Although the HFACS taxonomy has existed for several years, it has only recently been implemented in the Navy. It would be unreasonable to expect more than a passing familiarity with DoD-HFACS for the vast majority of Naval aircrews.

D. DATA ANALYSIS METHOD

The availability of data and the collection method of the CNAF strategic human factors review limit the type of analysis that could be done. First, only Navy squadrons were tasked to generate a top five human factors list. This means CNAF data can be compared to Naval Safety Center DoD-HFACS mishap data for Navy F/A-18s and H-60s only. Second, the only data available from CNAF is a summary of the top five concerns of each type wing. The complete dataset of each squadron is no longer available. This limits analysis to the nanocode level, as nanocodes cannot be accurately compiled into categories without the complete dataset.

The summary by type wing presents an additional challenge. There are two Navy type wings that operate F/A-18s and four that operate H-60s. Top five lists from individual squadrons were consolidated by type wing at CNAF. The result of this collection method is that there are two separate F/A-18 top five human factors lists, one for the type wing of East coast-based squadrons and one for the type wing of West coast-based squadrons.

For H-60s, the information is even more convoluted. There are two type wings on each coast, resulting in four different top five human factor lists. Further complicating matters is the fact that one of the four helicopter wings contains two squadrons that fly the H-53 Sea Dragon in addition to the 11 squadrons that fly the H-60. Since the full dataset by squadron is unavailable, both helicopter types are combined and cannot be separated. The lack of a complete dataset of responses also prohibits combining the four type wings into a single list. Therefore, all type wing lists will be presented individually.

Statistical comparison between CNAF human factors review data and mishap is also problematic. The CNAF human factors data represents the number of times each nanocode was chosen as one of a squadron's top five concerns. DoD-HFACS mishap data has thus far been presented as the rate at which nanocodes occurred per 100,000 flight hours. In order to present some common framework between the two datasets, percentages and rank order were used. For mishap data, rank order simply listed the top five most frequently occurring nanocodes. For CNAF data, rank order was based on the number of responding squadrons that listed a given nanocode as one of their top five concerns (i.e., the nanocode that was listed by the most squadrons as a top five concern would be ranked number one and so on).

For percentages, individual DoD-HFACS nanocode counts were analyzed as a percentage of the total number of mishaps cited in Naval Safety Center mishap data involving that aircraft. For example, the Naval Safety Center records 47 class A mishaps involving F/A-18s between FY2000 and FY2008. The number one occurring nanocode in those 47 mishaps is over/undercontrol, which was cited in 14 mishaps, or 29.8%. It is important to note that since many nanocodes can be cited in a single mishap, these percentages do not sum to 100%.

For CNAF human factors review data, the percentage of responding squadrons who listed a specific nanocode as being a top five concern were presented as a measure of common perception of risk within that type wing. For example, 12 out of 13 responding squadrons (92.3%) in the East coast F/A-18 type wing (CSFWL) chose ops tempo/workload among their top five human factors concerns. This percentage indicates that ops/tempo workload appears to be a commonly perceived risk among those squadrons. As with the mishap data percentages, because each squadron chose five nanocodes, the percentages do not sum to 100%. It is important to realize that the percentage figures for both mishap and CNAF data are not equivalent. Percentages are only presented to convey a sense of the distribution of each dataset.

E. RESULTS OF CNAF STRATEGIC HUMAN FACTORS REVIEW

The results of this analytical effort focused on two Navy aircraft platforms: the F/A-18 strike fighter and the H-60 helicopter. For each aircraft, a table was developed comparing the results from the analysis of Naval Safety Center mishap data and CNAF human factors strategic review data for two type wings. The first column lists the top five nanocodes cited in mishaps for the relevant aircraft platform as determined in the first analytical effort of this thesis. The second column is the percentage of class A mishaps in which the corresponding nanocode was cited as a casual factor. The third column lists the five nanocodes identified by the squadrons in the relevant type wing as being a top five human factors concern during the CNAF strategic human factors review. The fourth column lists the percentage of responding squadrons that identified the corresponding nanocode in their top five list of concerns. The fifth column shows where the CNAF nanocode appeared in the Naval Safety Center ranking of nanocodes and the percentage of mishaps in which it was identified as a casual factor. Columns six through eight present the same data as column three through five for the second type wing.

1. Navy F/A-18

Navy F/A-18 squadrons are divided between two type wings: Commander, Strike Fighter Wing Atlantic (CSFWL), which oversees all East coast-based squadrons and Commander, Strike Fighter Wing Pacific (CSFWP), which oversees all West coast-based squadrons. Table 12 summarizes the top five nanocodes and rankings for all Naval Safety Center mishap data as well as the CNAF strategic human factors review data from both F/A-18 type wings.

From the first analytical effort, the top four mishap nanocodes for all Navy F/A-18s are at the acts level, with the top three being skill-based errors. Only one nanocode from any other level, mental fatigue from the preconditions level, was listed. CNAF human factors data from both type wings overwhelmingly identified ops tempo/workload at the organizational level as the most likely cause of future mishaps. In contrast, the ops tempo/workload nanocode was only cited in 4.3% of F/A-18 mishap investigations. One act nanocode, procedural error, was ranked second for both the mishap and the West coast type wing datasets. Complacency and motivation exhaustion (burnout) were identified as a top five concern of type wings on both coasts. Although complacency was cited in 8.5% of F/A-18 mishap investigations, motivation exhaustion (burnout) has yet to be cited once. That is also the case with proficiency, a supervisory level nanocode identified by the East coast F/A-18 type wing.

Table 12. Navy F/A-18 Naval Safety Center Mishap and CNAF Strategic Human Factors Review DoD-HFACS Nanocode Ranking and Comparison

Safety Center Mishap Data Top 5 Nanocodes	% Mishap Contribution (47 total mishaps)	CSFWL (East Coast F/A-18s) Top 5 Nanocodes	% Squadrons Reporting as a Top 5 Concern (13 sqdns)	Rank/ % in Mishap Data	CSFWP (West Coast F/A-18s) Top 5 Nanocodes	% Squadrons Reporting as a Top 5 Concern (19 sqdns)	Rank/ % in Mishap Data
Over/Undercontrol	29.8%	Ops Tempo/Workload	92.3%	32* / 4.3%	Ops Tempo/Workload	68.4%	32* / 4.3%
Procedural Error	27.7%*	Proficiency	46.2%	64* / 0.0%	Procedural Error	42.1%*	2* / 27.7%
Breakdown in Scan	27.7%*	Cognitive Task Oversaturation	38.5%*	7* / 14.9%	Complacency	42.1%*	18* / 8.5%
Decision Making	23.4%	Complacency	38.5%*	18* / 8.5%	Task Misprioritization	36.8%	32* / 4.3%
Mental Fatigue	21.3%	Motivational Exhaustion (Burnout)	38.5%*	64* / 0.0%	Motivational Exhaustion (Burnout)	31.6%	64* / 0.0%

* indicates a tie ranking with other nanocodes

2. Navy H-60

Navy H-60 squadrons are divided amongst four type wings based on geographic location and mission. Commander, Helicopter Maritime Strike Wing Atlantic (CHSMWL) and Commander, Helicopter Sea Combat Wing Atlantic (CHSCWL) oversee all H-60 squadrons on the East coast. Additionally, CHSCWL also oversees two H-53 squadrons. As previously mentioned, the H-53 CNAF data is intermixed among the H-60 data and cannot be separated. For the West coast, Commander, Helicopter Maritime Strike Wing Pacific (CHSMWP) and Commander, Helicopter Sea Combat Wing Pacific (CHSCWP) oversee all H-60 squadrons exclusively. Tables 13 and 14 each contain the top five most frequent nanocodes for the Naval Safety Center H-60 mishap data. Table 13 compares that mishap data to East and West coast maritime strike helicopter squadrons, while Table 14 compares the same mishap data to East and West coast sea combat helicopter squadrons.

A review of the top five mishap nanocodes from the first analytical effort reveals three acts: procedural error, over/undercontrol, and risk assessment, one precondition: cross-monitoring performance, and one supervisory nanocode: inadequate supervision in the top five mishap nanocodes. In contrast, only one acts level nanocode (task misprioritization) was identified by only one of the four CNAF type wing top five list of human factors concerns. Eleven preconditions, seven supervisory, and six organizational nanocodes dominated the top concerns of H-60 squadrons. Ops tempo/workload, a top concern with F/A-18s squadrons was also the top concern of three of four helicopter type wings (although it has yet to be cited in any helicopter mishap). Proficiency, a supervisory nanocode appeared on all four type wings' top five lists which also has not been cited in a single helicopter mishap. Motivational exhaustion (burnout) and complacency are two precondition nanocodes that appeared on the top five lists of three of the four type wings as well. Complacency was cited in 25% of helicopter mishaps, yet motivational exhaustion (burnout) has not been cited at all.

Table 13. Navy H-60 Naval Safety Center Mishap and Maritime Strike Helicopter CNAF Strategic Human Factors Review DoD-HFACS Nanocode Ranking and Comparison

Safety Center Mishap Data Top 5 Nanocodes	**% Mishap Contribution (16 total mishaps)**	**CHSMWL (East Coast H-60s) Top 5 Nanocodes**	**% Squadrons Reporting as a Top 5 Concern (6 squadrons)**	**Rank/ % in Mishap Data**	**CHSMWP (West Coast H-60s) Top 5 Nanocodes**	**% Squadrons Reporting as a Top 5 Concern (9 squadrons)**	**Rank/ % in Mishap Data**
Procedural Error	68.8%	Ops Tempo/Workload	66.7%*	53* / 0.0%	Proficiency	66.7%	53* / 0.0%
Over/Undercontrol	56.3%	Complacency	66.7%*	8* / 25.0%	Complacency	44.4%*	8* / 25.0%
Risk Assessment	37.5%*	Overconfidence	50.0%*	21* / 12.5%	Mental Fatigue	44.4%*	21* / 12.5%
Cross-monitoring Performance	37.5%*	Distraction	50.0%*	31* / 6.3%	Motivational Exhaustion (Burnout)	33.3%*	53* / 0.0%
Supervision Inadequate	37.5%*	Proficiency	50.0%*	53* / 0.0%	Limited Total Experience	33.3%*	53* / 0.0%

***** indicates a tie ranking with other nanocodes

Table 14. Navy H-60 Naval Safety Center Mishap and Sea Combat Helicopter CNAF Strategic Human Factors Review DoD-HFACS Nanocode Ranking and Comparison

Safety Center Mishap Data Top 5 Nanocodes	**% Mishap Contribution (16 total mishaps)**	**CHSCWL (East Coast H-60s) Top 5 Nanocodes**	**% Squadrons Reporting as a Top 5 Concern (13 sqdns)**	**Rank/ % in Mishap Data**	**CHSCWP (West Coast H-60s) Top 5 Nanocodes**	**Number of Squadrons Reporting as a Top 5 Concern (unknown) †**	**Rank/ % in Mishap Data**
Procedural Error	68.8%	Ops Tempo/Workload	53.8%*	53* / 0.0%	Ops Tempo/Workload	10	53* / 0.0%
Over/Undercontrol	56.3%	Proficiency	53.8%*	53* / 0.0%	Proficiency	8	53* / 0.0%
Risk Assessment	37.5%*	Complacency	38.5%	8* / 25.0%	Operator Support	6*	53* / 0.0%
Cross-monitoring Performance	37.5%*	Motivational Exhaustion (Burnout)	23.1%*	53* / 0.0%	Organizational Structure	6*	53* / 0.0%
Supervision Inadequate	37.5%*	Cognitive Task Oversaturation	23.1%*	53* / 0.0%	Task Misprioritization	4*	13* / 18.8%
		Limited Total Experience	23.1%*	53* / 0.0%	Motivational Exhaustion (Burnout)	4*	53* / 0.0%
		Limited Recent Experience	23.1%*	53* / 0.0%	Cognitive Task Oversaturation	4*	53* / 0.0%
					Unit/Mission/Aircraft Change or Deactivation	4*	53* / 0.0%

* indicates a tie ranking with other nanocodes
† The total number of reporting squadrons in this type wing was unavailable. Therefore, instead of percentages, the number of squadrons who listed a particular nanocode in their top five human factors concerns is presented.

F. DISCUSSION OF CNAF STRATEGIC HUMAN FACTORS REVIEW

The first goal of this analytical effort was to examine the results of the CNAF strategic human factors review conducted in the spring of 2008 to determine the nanocodes identified by Navy F/A-18 and H-60 squadrons as most likely to be casual factors in future mishaps. It can be seen in Table 15 that ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) appeared in the top five list of concerns of five of the six type wings for both F/A-18 and H-60 squadrons. Although there are some differences of rank order within the top five for each type wing, there is a large degree of commonality across aircraft platforms. In fact, ops tempo/workload was the number one nanocode in five of the six type wings examined. It is important to note that the CNAF strategic human factors review depicts a single snapshot taken during a time when the United States was currently engaged in two large military actions in Iraq and Afghanistan. It should probably not be surprising then that factors such as ops tempo/workload, complacency, and motivation exhaustion (burnout) are common concerns for operational aircrews.

Table 15. Most Popular DoD-HFACS Nanocodes in Type Wings' Top Five Lists and Comparison to Navy Safety Center Mishap Data

DoD-HFACS Nanocode	Number (%) of F/A-18 and H-60 Type Wings That Listed Nanocode as a Top Five Concern	% of F/A-18 Mishaps That Cited Nanocode	% of H-60 Mishaps That Cited Nanocode
Ops Tempo/Workload	5 (83.3%)*	4.3%	0.0%
Proficiency	5 (83.3%)*	0.0%	0.0%
Complacency	5 (83.3%)*	8.5%	25.0%
Motivational Exhaustion (Burnout)	5 (83.3%)*	0.0%	0.0%
Cognitive Task Oversaturation	3 (50.0%)	14.9%	0.0%

***** indicates a tie with other nanocodes

G. RESULTS OF COMPARISON BETWEEN NAVAL SAFETY CENTER MISHAP DATA AND CNAF STRATEGIC HUMAN FACTORS REVIEW

The second goal of this analytical effort is to compare the results from the CNAF strategic human factors review to the results from the Naval Safety Center mishap data presented in Chapter III. Table 15 illustrates that the concerns identified in the CNAF strategic human factors review were not the same as the leading mishap causes cited in the Naval Safety Center's database. The heightened level of operations previously mentioned might account for the fact that current human factors concerns today differ from historical causes of mishaps over the last nine years. However, the United States has been engaged in both Iraq and Afghanistan since 2003, representing over half of the time period in question. Therefore, it should reasonably be expected to see at least one instance of ops tempo/workload or motivational exhaustion (burnout) cited in a mishap between FY2000 and FY2008.

Table 16 offers another comparison between the mishap and CNAF data. It shows the level (acts, preconditions, supervisory, or organization) of the top five nanocodes listed in Tables 12, 13, and 14. Table 16 clearly illustrates that in the mishap data, the majority of the nanocodes are from the acts level. However, act level nanocodes only appear in two of the type wings' top five lists. Nanocodes at the precondition and supervisory levels comprise the majority of human factor concerns among F/A-18 and H-60 squadrons. This indicates a distinct difference in the type of nanocodes perceived as a threat to safety by operational aircrews and the nanocodes actually cited in mishap investigations. More specifically, when asked, aircrews seem to be more likely to look higher up the sequence chain of events than mishap investigators.

Table 16. Comparison of the DoD-HFACS Levels of Top Five Nanocodes in Naval Safety Center Mishap Data and CNAF Strategic Human Factors Data

Mishap Data		**CNAF Strategic Human Factors Review Data**					
F/A-18 Safety Center Mishap Data Top 5 Nanocodes	**H-60 Safety Center Mishap Data Top 5 Nanocodes**	**CSFWL (East Coast F/A-18s) Top 5 Nanocodes**	**CSFWP (West Coast F/A-18s) Top 5 Nanocodes**	**CHSMWL (East Coast H-60s) Top 5 Nanocodes**	**CHSMWP (West Coast H-60s) Top 5 Nanocodes**	**CHSCWL (East Coast H-60s) Top 5 Nanocodes**	**CHSCWP (West Coast H-60s) Top 5 Nanocodes**
Act	Act	Organization	Organization	Organization	Supervisory	Organization	Organization
Act	Act	Supervisory	Act	Precondition	Precondition	Supervisory	Supervisory
Act	Act	Precondition	Precondition	Precondition	Precondition	Precondition	Organization
Act	Precondition	Precondition	Act	Precondition	Precondition	Precondition	Organization
Precondition	Supervisory	Precondition	Precondition	Supervisory	Supervisory	Precondition*	Act*
						Supervisory*	Precondition*
						Supervisory*	Precondition*
							Organization*

* indicates a tie ranking with other nanocodes

H. DISCUSSION OF COMPARISON BETWEEN NAVAL SAFETY CENTER MISHAP DATA AND CNAF STRATEGIC HUMAN FACTORS REVIEW

The comparison between the Naval Safety Center mishap data and the CNAF strategic human factors review revealed a difference in the DoD-HFACS level in which the leading nanocodes were selected. Mishap investigators tended to identify acts as the leading causes of mishaps, while squadrons responded that preconditions, supervisory, and organizational level nanocodes were the most likely causes of future mishaps. This disparity may represent a shift in the causes of mishaps, but more likely is the result of biases inherent in the sources of data.

One possible reason for the bias of investigators towards nanocodes at the acts level is inherent in the investigation process. A mishap investigation generally starts at the crash site and works backwards in time to establish the sequence of events that caused the accident. Therefore, act level nanocodes are the first human factors encountered by investigators. Additionally, act level nanocodes are often the easiest nanocodes of which to find conclusive evidence. For example, it easy to assign a nanocode of checklist error to a mishap resulting from an attempted landing with the landing gear retracted. A decision to continue a landing approach during a severe thunderstorm can likewise be easily assigned a nanocode of decision-making. Moving further up the hierarchy of DoD-HFACS, a thorough investigation may uncover evidence of nanocodes at the precondition level such as inadequate rest by interviewing the pilot's spouse or roommates about his or her recent sleep habits.

As investigators move further up the levels of DoD-HFACS however, many nanocodes become vague and difficult to conclusively determine from the evidence. Ops tempo/workload, an organizational level nanocode identified as the top concern of five type wings, may be extremely difficult to authoritatively cite in a mishap investigation. Consider a deployed squadron that is operating at an intense pace with most pilots flying two or more times a day for weeks on end. On one such flight, the pilot makes a grave judgment error that results in a mishap. After investigators identify nanocodes at the acts, preconditions, and supervisory levels, they might consider that the recent ops tempo of the squadron influenced the stress levels and amount of rest available to the mishap pilot. However, how do investigators demonstrably prove ops tempo was a factor? Every other pilot in the squadron was operating under similar stress at the same operational tempo, yet they had not had a mishap. Investigators may be reluctant to assign an ops tempo/workload nanocode even in a highly stressful operational environment based on the relative success of the mishap pilot's peers at avoiding a mishap. Therefore, these broad and often vague nanocodes, particularly at the supervisory and organizational level may be absent from mishap investigation data because of the difficulty in finding conclusive proof.

A number of authors have identified biases that may have been present in the mishap investigations and CNAF strategic human factors review (Woodcock, 1995; Hofmann & Stetzer, 1998). The tendency to place blame on individuals rather than circumstances is called fundamental attribution error and is believed by many researchers to be an inherent bias in many accident investigations (Hofmann & Stetzer, 1998). This attribution error may be one reason mishap nanocodes are more prevalent in the act and preconditions levels, which are most closely associated with individuals, vice surrounding circumstances. The supervisory and organizational levels of DoD-HFACS attempt to capture the influence of the larger situational context on the occurrence of the mishap. Fundamental attribution error may be inhibiting these factors from being captured in the Naval Safety Center's mishap database.

In contrast, respondents in the CNAF strategic human factor review were not constrained by normal mishap investigation procedures. It is unlikely that respondents began with the acts of a hypothetical mishap and worked backwards as mishap investigators would. These respondents were free to choose the nanocodes they believed most likely to cause future accidents without constraint. Respondents also were not burdened with providing evidence to support their assertions of likely contributors to future mishaps. Their choices for the top human factors concerns were undoubtedly driven by their experiences of mitigating risks during flight operations on a daily basis. As a result, squadrons' choices of nanocodes represented a more diverse distribution across all levels of DoD-HFACS. It is likely some real concerns that were not captured in the Naval Safety Center mishap data were brought to light in the CNAF strategic human factors review. However, the choices made by squadrons are not immune from inherent biases of their own.

Defensive attribution bias is the tendency of individuals to identify with accident victims and therefore attribute mishap causes to situational factors rather than personal factors (Hofmann & Stetzer, 1998). Defensive attribution bias may be the reason few act-level nanocodes found their way into the top five concerns in the CNAF dataset. Few pilots would willingly admit their lack of skill or flawed judgment would most likely cause the next mishap. It is far more likely they would identify external factors that could impair their otherwise error-free performance. This bias may explain the prevalence of nanocodes at the preconditions, supervisory, and organizational level in the CNAF results.

The discussion of fundamental attribution error and defensive attribution bias is not intended to cynically criticize the sources of either the mishap or the CNAF datasets. The contributors to both were assuredly honest, well-meaning individuals who reached their conclusions after careful consideration. That being said, the discussion of the possible presence of biases is meant to offer an explanation for the differing results from each dataset. Ground truth of the actual proportion of responsibility between individuals and the surrounding circumstances can never be known. However, viewing aircraft mishaps from differing perspectives is likely to lead to safety that is more effective.

I. CONCLUSION

The results of the CNAF strategic human factors review indicated that F/A-18 and H-60 squadrons perceive ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) as the most likely causes of future mishaps. These human factors differed sharply from the leading causes of mishaps cited in the Naval Safety Center database: skill-based errors and coordination/communication/planning factors. Although the situational factors identified by aircrews and the personnel factors identified by mishap investigators may have been influenced by inherent biases based upon their perspectives, taken together, they represent a more complete picture of all the contributors to a mishap. If mishap interventions are to be successful, they must take all of these factors into account. This is particularly true when considering the design of next generation aircraft. The next chapter will explore using a human systems integration approach to generate mishap interventions for future aircraft system designs.

V. MISHAP INTERVENTION DEVELOPMENT

A. BACKGROUND

As illustrated in the two previous chapters, trying to get at the causes of mishaps can be difficult enough. However, the purpose of the investigation is to prevent similar mishaps from occurring in the future. While it may seem that once the causes are known, the solutions are self-evident, rarely is this actually the case. This is particularly true with skill-based and judgment and decision-making errors made at the act level. At first glance, it may seem that mandating more practice and training might help keep a pilot from forgetting an item on a checklist, but perhaps the problem doesn't lie with the familiarity of the checklist at all. Perhaps the true issue lies in changing the preconditions that allowed that pilot to become distracted or prone to being forgetful. The advantage of the HFACS taxonomy is the ability to identify higher-level influences and intervene appropriately.

Although historical mishap investigations and aircrew surveys can provide useful data to safety professionals for the prevention of mishaps in current systems, they can also aid in the design and incorporation of mishap prevention measures into future systems as well. The range of possible interventions available in current aircraft is often limited. While many possible interventions are relatively inexpensive (new procedures, additional training), others are not (redesign of navigation or flight management systems). However, in the design phase of future aircraft, many more options are available to guard against future mishaps. This is why it is critical for acquisition program managers and HSI practitioners working on future aircraft to consider safety from the very beginning. Lessons learned from current generation aircraft mishaps can provide valuable insight into the likely sources of human error in future systems. Decisions made early in the design process can lead to an aircraft that supports human decision making and prevents common errors, or saddles future pilots with an ineffectual system fraught with opportunities for error.

B. OBJECTIVE

The objective of this analytical effort is the development of a pilot methodology for mishap intervention generation and evaluation. A recently developed system called the Human Factors Intervention Matrix (HFIX) will be presented and used as the basis of a human systems integration (HSI) approach to mishap prevention. HFIX will be evaluated for completeness and modified as necessary in order to produce a complete methodology for use by safety professionals in influencing the design of future aircraft systems.

C. HUMAN FACTORS INTERVENTION MATRIX (HFIX)

Shappell and Wiegmann (2006, 2009, in press), the creators of the HFACS taxonomy, recognized that categorizing the human factors causes of mishaps was only a partial solution to mishap prevention. There was also a need to develop a system that would aid investigators in identifying methods for preventing similar mishaps from occurring in the future. With this in mind, they created a methodology for mishap intervention development called the Human Factors Intervention Matrix (HFIX). The purpose of HFIX is to aid decision makers in considering several possible categories for mishap interventions (Shappell & Wiegmann, 2006). Additionally, HFIX provides a method to evaluate possible intervention strategies and make comparisons between them. Although HFIX is a relatively new and untested methodology that has only been used in a few studies of general and commercial aviation by its authors (Shappell & Wiegmann, 2009, in press), its shows promise as a companion to the HFACS taxonomy. The basic HFIX process as described by Shappell and Wiegmann (2006, 2009, in press) will be delineated. Next, modifications to HFIX will be proposed that incorporate the lessons learned from the first two analytical efforts, the domains of HSI, and the Joint Capabilities Integration and Development System.

The HFIX methodology is designed to develop intervention strategies targeted at preventing or mitigate errors within the four act-level categories of

HFACS: decision errors, skill-based errors, perceptual errors, and violations (Shappell & Wiegmann, 2006). In order to accomplish this, five broad areas of intervention, or domains, are proposed by Shappell and Wiegmann (2006, 2009, in press): organizational/administrative, human/crew, technology/engineering, task/mission, and operational/physical environment (Table 17 defines each of the domains). The HFIX matrix, shown in Figure 33, helps guide safety professionals in the development of interventions for each category of human error through a series of brainstorming sessions.

Table 17. Domains of Human Factors Intervention Matrix (HFIX) (From: Shappell & Wiegmann, in press)

Administrative
Human Resource Management: Adequacy of staff in specific situations, the need for additional personnel, and the evaluation of individual skills of employees.
Rules/Regulations/Policies: Issuing, modifying, establishing, amending, and/or reviewing policies, rules, or regulations.
Information Management/Communication: Improvements in disseminating, storing, archiving and publishing information. Also included are recommendations regarding collection of data, issuing information, and reporting activity.
Research/Special Study: Conducting research to determine the impact of recent technological advances or call for special studies to review processes, develop/validate methodologies, etc.
Task
Procedures: Amending, reviewing, modifying, revising, establishing, developing, and validating procedures.
Manuals: Reviewing, revising, issuing, and modifying manuals, bulletins, checklists, and other instructions or guidance.
Technological
Design/Repair: Specific manufacturing changes including the design of parts. Also included is the modification, replacement, removal and/or installation or repair of parts and equipment.
Inspection: Maintenance inspections, overhauling, detecting damage including day-to-day operations such as inspecting fuel, oil level, and recommended safety checks.
Operational Environment
Operational/Physical Environment: Modifications to the operational environment (e.g., weather, altitude, terrain) or the ambient environment, such as heat, vibration, lighting, eliminating toxins, etc. to improve performance.
Human/Crew
Training: Reviewing, developing, and implementing training programs. Also included is the training of personnel in handling emergencies.

	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/ Physical Environment
Decision Errors					
Skill-based Errors					
Perceptual Errors					
Violations					

Figure 33. Domains of Human Factors Integration Matrix (From: Shappell & Wiegmann, 2006)

The first phase of the HFIX methodology is intervention generation. Shappell and Wiegmann (in press) recommend gathering a group of 20 individuals with a variety of experiences and backgrounds for this task. For aviation mishap intervention generation, participants should include aircrew, maintainers, logisticians, administrators, and air traffic controllers. Ideally, all participants should be instructed to dress casually and no formal introductions should be made. The purpose of these steps is to help conceal each individual's place within the organization in order to avoid any real or perceived rank or authority gradients.

The 20 participants are then randomly assigned to one of five working groups. Each working group is assigned an intervention domain (e.g., technology/ engineering) and a particular mishap cause. The group is then given 15 minutes to generate as many interventions within that domain as possible. At this point, no idea is considered too far-fetched and no effort is made to evaluate interventions. After 15 minutes, the group is prompted with a sheet of questions in order to further stimulate the generation of new interventions. Two examples of these questions from the technology/engineering domain are: “How could controls be more easily identified, and/or better designed in terms of shape, size, and other relevant considerations?” and “How could information sources be integrated or located in an effective manner?” (Shappell & Wiegmann, in press). After another 15 minutes of intervention generation, each workgroup adopts a new intervention domain (e.g., task/mission) and repeats the process.

Once a list of suggested interventions has been created for each domain, the evaluation process begins. In this process, a smaller group of experts then rates each proposed intervention on a scale of one to five for each of the five criteria known as “FACES”: feasibility, acceptability, cost, effectiveness, and sustainability. Using a rating of “one” for poor and “five” for excellent, the participants rate each intervention on every evaluation criterion. All individual ratings for each criterion are then averaged together to arrive at a group average rating for feasibility, a group average rating for acceptability, and so on. Explanations and examples of the FACES criteria are given below.

1. Feasibility

Feasibility refers to the ease with which an intervention could be implemented. For example, one possible intervention to reduce the number of mishaps that occur at night due to a lack of proficiency might be to eliminate night flight operations altogether. Clearly this is not a very feasible option for the U.S. military. However, increasing the number of night flight hours each pilot must log every month is a much more feasible intervention.

2. Acceptability

Acceptability is the extent to which personnel affected by the intervention will be agreeable to it. To illustrate, mandating the use of autopilot landing systems 100% of the time might reduce pilot skill-based error mishaps in the landing phase, but few pilots will find that an acceptable solution.

3. Cost

Cost refers to the financial burden of implementing the intervention. This cost could be direct (dollar amount) or indirect (an increased number of personnel required, which will in turn raises monetary costs).

4. Effectiveness

Effectiveness is the ability of the intervention to eliminate or reduce the likelihood of a mishap. Effectiveness is a given requirement of any intervention strategy, but rating its likelihood in preventing future mishaps allows comparison among multiple intervention strategies.

5. Sustainability

Sustainability is both the ability of the intervention to maintain its effectiveness over the long term and the organization's ability to support it. For example, briefing all aircrews on the causes of recent trends in mishaps may make them more aware of certain risk factors, but this awareness will likely fade with time.

Once every intervention strategy has been rated on the FACES criteria, comparisons between each strategy are made. An organization may choose to treat each of the FACES criterion as equally important. In that case, the ratings for each criterion are averaged together to create a single number rating for each intervention. Rank ordering of the interventions by this single rating would reveal the interventions most worth pursuing. However, some organizations may wish to prioritize some criteria over others. For example, Navy leadership may place less emphasis on acceptability if it is felt that pilots can be ordered to accept whatever interventions are chosen. Likewise, if the consequences of failure are dire, cost may prove less a concern than effectiveness. In order to take these priorities into account, safety professionals can weight each criterion appropriately and determine which interventions best suit the needs of their organization (Shappell & Wiegmann, in press).

D. COMPARISON OF HUMAN FACTORS INTERVENTION MATRIX (HFIX) DOMAINS

Although the HFIX domains of organizational/administrative, human/crew, technology/engineering, task/mission, and operational/physical environment are intended to cover the scope of possible interventions, consideration of other domains is warranted. Two possible sources of alternative domains for intervention development are those of human systems integration and the Joint Capabilities Integration and Development System used in the DoD acquisition process. Each series of alternate domains will be discussed briefly and compared in order to arrive at the optimum set of possible domains for mishap intervention.

1. Human Systems Integration

Human systems integration (HSI) is an interdisciplinary approach to ensuring the human is thoroughly considered in the design, development, and integration of a new system. HSI considers the domains of manpower, personnel, training, human factors engineering, survivability, habitability, and safety and occupational health. Of all these domains of HSI, manpower, personnel, training, and human factors engineering are the primary domains that can be manipulated during the system acquisitions process in order to produce desired levels of personnel survivability, habitability, safety, and occupational health (Tvaryanas, Brown, & Miller, 2009). The HSI approach builds uses the strengths in each domain and performs tradeoffs between them in order to optimize total system performance. Minimizing human error and increasing safety is a necessary byproduct of this process. Therefore, the domains of HSI offer a broader alternative to the HFIX domains proposed by Shappell and Wiegmann (2006, 2009, in press).

2. Joint Capabilities Integration and Development System (JCIDS)

Another alternative framework for mishap intervention generation is the Joint Capabilities Integration and Development System (JCIDS). JCIDS is the means by which the DoD assesses military capability needs. A key part of the JCIDS process is the DOTMLPF analysis. DOTMLPF is an acronym for doctrine, organization, training, material, leadership, personnel, and facilities. The Defense Safety Oversight Council lists as one of its key tasks the examination of "existing systems, missions, processes, applications, policies, and programs through the DOTMLPF process to discover the best fit for human-systems capabilities and thereby facilitate mishap prevention and safety" (Chair, Defense Safety Oversight Council, 2008, p. 1). Therefore, it is appropriate that these domains be considered during intervention development. An explanation of each domain taken from the DoD's JCIDS Manual (Chairman, Joint Chiefs of Staff, 2009) is listed below:

- Doctrine: the fundamental principles that guide employment of U.S. forces.
- Organization: the structure by which individuals and units interact with one another to accomplish the mission.
- Training: the training and rehearsals of tactics, techniques, and procedures used in the execution of the mission.
- Material: all items (including weapons systems, parts, and supplies) necessary to operate and support military forces.
- Leadership: the training, education, experience, and self-improvement required to develop the most professionally competent individual possible.
- Personnel: qualified personnel who are able to support the mission.
- Facilities: buildings, structures, and installations equipped to support military operations.

The domains of DOTMLPF are those considered when the DoD develops or modifies a military capability. Each of these domains represents a possible solution for bridging an identified capability gap. These domains also provide another set of domains from which mishap intervention strategies could be developed.

3. Comparison of Mishap Intervention Areas with Domains of HFIX, HSI, and DOTMLPF

The main purpose of the domains of HFIX is to provide structured guidance to the brainstorming sessions in the intervention generation phase. Additionally, the domains provide a checklist of areas of consideration to ensure a thorough search for intervention strategies has been conducted. In order to be effective, the list of domains should be comprehensive, and address all possible intervention strategies. In addition, the individual domains must not be too general to ensure that all areas are given adequate attention. A list of possible mishap intervention areas was generated incorporating the definitions of the domains of HFIX, HSI, and DOTMLPF and is presented in Table 18. This list is intended to provide the full range of choices from which mishap intervention strategies could be developed. For each one of these mishap intervention areas, the appropriate domain (if available) from HFIX, HSI, and DOTMLPF is noted.

Table 18. Crosswalk of Mishap Intervention Areas With Domains of HFIX, HSI, and DOTMLPF

Mishap Intervention Area	HFIX Domains	HSI Domains	DOTMLPF Domains
Number Of Personnel	Organizational/ Administrative	Manpower	Personnel
Personnel Skill Sets And Qualifications	Organizational/ Administrative	Personnel	Personnel
Rules / Policies / Regulations	Organizational/ Administrative		
Informational Management / Communication	Organizational/ Administrative		
Research/Special Study	Organizational/ Administrative		
Procedures / Manuals	Task/Mission		
Design / Repair	Technology/ Engineering	Human Factors Engineering	Material
Operational / Physical Environment	Operational/ Physical Environment		
Training	Human/Crew	Training	Training / Leadership
Doctrine			Doctrine
Organizational Structure	Organizational/ Administrative		Organization
Organizational Culture	Organizational/ Administrative		Organization
Supporting Facilities			Facilities

Table 18 illustrates that no single set of domains addresses every mishap intervention area listed. This suggests that no one set is adequate to ensure all possible intervention strategies are covered. Additionally, one of the HFIX domains, in particular, encompasses a wide range of intervention areas. The broad spectrum of the HFIX organizational/administrative domain covers everything from the number and skill sets of personnel, to rules and regulations, to organizational structure. This broad domain lacks the specificity to ensure no possibilities are overlooked. Breaking the organizational/administrative domain into a few explicit domains would likely ensure each of the intervention areas are adequately scrutinized.

E. RECOMMENDED MISHAP INTERVENTION DOMAINS

After careful consideration of the mishap intervention areas and domains presented, Table 19 is offered as an alternative to the lists of domains described above. The resulting list of domains incorporates the best attributes of HFIX, HSI, and DOTMLPF to represent the full spectrum of intervention options available to safety professionals. The eight recommended mishap intervention domains are: mission, manpower, personnel, training, human factors engineering, policy/ procedures, leadership, and facilities/environment. Table 19 gives a brief description of each domain and two fundamental questions that guide safety professionals in developing interventions within that domain.

Table 19. Recommended Mishap Intervention Domains

Domain	Description/Questions
Mission	The assigned mission of the aircraft, personnel, or system. - Is the mission necessary? - Can the mission be modified to reduce the threat of a mishap?
Manpower	The number and type of military, DoD civilians, and contractors needed to operate, support, and maintain a system. - Would increasing or decreasing the number of personnel reduce the likelihood of a mishap? - Would changing the type of personnel (contractor, DoD civilian, military) reduce the likelihood of a mishap?
Personnel	The human performance characteristics required of a system's user population to include their knowledge, skills, and abilities. - Do personnel recruited have the necessary abilities to operate the system? - Could modifying selection criteria reduce the likelihood of a mishap?
Training	The means to enhance and maintain the knowledge, skills, and abilities of a system's operators, maintainers, and support personnel to ensure optimal performance. - Is existing training adequate to maintain the skills and abilities of personnel? - Would additional training reduce the likelihood of a mishap?
Human Factors Engineering	The optimization of human-machine interface in the design and engineering of a system, accounting for the physical, sensory, and cognitive characteristics of the user population. - Does the design of the system fit the characteristics of the user population? - Is there a more effective information or control interface between the system and the user?
Policy/ Procedures	The policies, rules, regulations, procedures, and documentation such as manuals that support a system. - Are the procedures and documentation for the system's operation and maintenance accurate? - Are there sufficient rules and regulations governing safe operation of the system?
Leadership	The structure, culture, and guidance of an organization in the conduct of its mission. - Does the culture and structure of an organization support the safe operation of the system? - Are violations of rules and regulations swiftly corrected or tolerated?
Facilities/ Environment	The buildings, facilities, operating environment in which the system is operated. - Are the system's facilities adequate to support safe operations? - Can the environment be manipulated to reduce the likelihood of a mishap?

F. HFACS LEVELS EVALUATED IN HFIX

The results from the first two analytical efforts demonstrated a diverse range of human errors that cause aircraft mishaps. While the examination of mishap data revealed act-level nanocodes of errors, the CNAF strategic human factors review pointed towards nanocodes at the higher preconditions, supervisory, and organization levels. As originally proposed by Shappell and Wiegmann (2006, 2009, in press), HFIX only addresses the HFACS categories at the acts level. If mishap investigations were used as the sole predictor of future causes of mishaps, the first analytical effort of this thesis would support that design. However, the CNAF strategic human factors review revealed that aircrews' perceptions of future causes of mishaps belonged to higher levels of HFACS that would not be addressed by HFIX. To account for these concerns, HFIX needs to be expanded.

In order to appropriately address the concerns of mishap investigators and aircrews, a mishap intervention generation methodology should be just as comprehensive in addressing the possible mishap causes as it is in the spectrum of domains it uses to generate solutions. Again, using the HFIX methodology as a starting point, it is recommended that the categories of HFACS examined be expanded to include all 20 categories of DoD-HFACS. Figure 34 incorporates all 20 DoD-HFACS categories and the eight mishap intervention domains discussed above. Using this revised HFIX matrix, safety professionals can address the full range of human error with a full spectrum of solutions.

	Mission	Manpower	Personnel	Training	Human Factors Engineering	Policy/ Procedures	Leadership	Facilities/ Environment
Skill-based Errors								
Judgment Decision-making Errors								
Perception Errors								
Violations								
Cognitive Factors								
Psycho-behavioral Factors								
Adverse Physiological Factors								
Physical/Mental Limitations								
Perceptual Factors								
Physical Environment								
Technological Environment								
Coordinating/Communication/ Planning Factors								
Self-imposed Stress								
Inadequate Supervision								
Planned Inappropriate Operations								
Failure to Correct Known Problem								
Supervisory Violations								
Resource/Acquisition Management								
Organizational Climate								
Organizational Process								

Figure 34. Revised HFIX Matrix with All DoD-HFACS Categories and Eight Mishap Intervention Domains (After Shappell & Wiegmann, 2006, 2009, in press)

Although the revised HFIX matrix is intended to be a more comprehensive methodology, the practical application of this larger matrix may seem daunting. However, in order to address the leading concerns of safety professionals, interventions need not be generated for the entire matrix. Rather, the revised

HFIX matrix is intended to be a menu from which safety concerns can be analyzed and intervention solutions generated. For example, the leading concerns from the first analytical effort's examination of Naval Safety Center mishap data were communication/coordination/planning factors and skill-based errors. Safety professionals interested in addressing these concerns need only conduct the revised HFIX process for those two categories. Using the CNAF strategic human factors review results from the second analytical effort, it would also be wise to conduct the HFIX process on the categories of organizational processes, planned inappropriate operations, psycho-behavioral factors, and cognitive factors.

Although picking and choosing from the menu of current DoD-HFACS categories of concern may be effective for reducing mishap rates in current systems, the design phase of future aircraft systems requires a more comprehensive process. In considering the design, manning, equipping, and operation of future aircraft systems, completing the revised HFIX matrix is a worthwhile investment. Although it might be time consuming to explore preventative strategies in each domain for each DoD-HFACS category, it would likely be more costly in time and financial resources to address deficiencies in a fielded system that could have been prevented with adequate forethought. As such, the revised HFIX matrix can provide assurances that the prevention of human error was given due consideration early in the acquisition process.

HFIX, as originally put forth by Shappell and Wiegmann (2006, 2009, in press), has not yet been widely scrutinized in safety research. Likewise, the revised HFIX framework presented in this thesis will have to be evaluated and adapted as required based on further research and application. A longitudinal study of human factors contributions to mishaps before and after its application would clearly yield the most effective evaluation of its worth. It is hoped that acquisitions professionals and HSI practitioners will find value in applying the revised HFIX methodology to a systematic safety review of future aircraft systems design.

G. CONCLUSION

The ultimate goal of any safety program is the prevention of future mishaps. The HFIX methodology is a useful process in the generation and evaluation of mishap intervention strategies. The purpose of this analytical effort was to expand the breadth and depth of HFIX to include all possible sources of intervention strategies and all possible sources of human error categorized by DoD-HFACS. The domains of HSI and DOTMLPF were explored and incorporated to expand the sources from which safety professionals can draw upon for solutions. As revealed by the results of the analysis of the CNAF strategic human factors review, sources of human error beyond the acts level can be important in the prevention of future mishaps. Addressing these human errors is important for an effective safety program. Finally, the design phase of future aircraft systems should include a comprehensive exploration of all sources of human error within the DoD-HFACS taxonomy and appropriate mishap intervention domains applied to produce a safe and operationally effective system.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The purpose of this thesis was to determine the leading causes of Naval Aviation mishaps and develop a methodology for the generation and evaluation of mishap intervention strategies. To this end, three analytical efforts were conducted. The first effort was an analysis of Naval Aviation mishaps to determine the most frequently occurring type of human error. The second effort analyzed the results of a survey of Naval aircrews intended to determine the human errors perceived to be likely causes of future mishaps. The third effort explored and revised a methodology for developing mishap intervention strategies in current and future aircraft systems.

The first analytical effort of this thesis examined Naval Aviation mishap data from FY2000-FY2008. These mishap investigation reports were recently recoded into the Department of Defense Human Factors Analysis and Classification System (DoD-HFACS) taxonomy by a Naval Safety Center analyst. This taxonomy is a standard methodology to classify, catalog, and analyze the contribution of human error to mishaps. For the data available, the most commonly occurring DoD-HFACS categories were determined for the following communities: Navy and Marine Corps combined (F/A-18, AV-8B, H-60, H-53, H-46, UH-1, & AH-1W), overall Navy (F/A-18 & H-60), overall Marine Corps (F/A-18, AV-8B, H-53, H-46, UH-1, & AH-1W), Navy F/A-18, Marine Corps F/A-18, Navy Helicopter (H-60), and Marine Corps Helicopter (H-53, H-46, UH-1, & AH-1W). The top two categories across all communities were skill-based errors and coordination/communication/planning factors. In general, these two categories occurred at a much higher rate than other categories, doubling the occurrence rate of the third place category in many cases. Judgment and decision-making errors appeared in the top five list of all but Marine Corps helicopters, where it placed seventh. Comparing these results to other aviation mishaps studies that have used HFACS, revealed a degree of commonality in the type of human errors involved in all aviation mishaps (both commercial and military).

The second analytical effort examined the results of a strategic human factors review conducted by the Commander, Naval Air Forces (CNAF) in the spring of 2008. As part of this review, each individual squadron was directed to identify their top five human factors concerns. This data was collected using the nanocodes of the DoD-HFACS classification system. Squadrons were instructed that they could analyze current issues or try to predict the cause of the next mishap. Results from each squadron were compiled at the appropriate type wing (a collection of several squadrons operating similar aircraft platforms) and relayed to CNAF. To allow comparison with the results from the first analytical effort, only F/A-18 and H-60 aircraft data was analyzed. Five out of six type wings for F/A-18 and H-60 squadrons identified ops tempo/workload, proficiency, complacency, and motivational exhaustion (burnout) as being among their top five concerns. These nanocodes belong to the DoD-HFACS levels of organization, supervision, and preconditions, which sharply contrasted the act-level errors identified in the mishap data from the first analytical effort. While this difference could be influenced by biases inherent in the points of view of mishap investigators and aircrews, it also demonstrates that mishap investigations do not tell the complete story in regards to the causes of mishaps. In order for safety professionals to fully understand all the influential factors causing mishaps, both perspectives must be considered.

The third analytical effort examined a mishap intervention and evaluation methodology, called the Human Factors Intervention Matrix (HFIX), proposed by Shappell and Wiegmann (2006, 2009, in press). A number of recommendations were suggested based upon the unique needs of the Navy to make the framework more useful for program managers involved in the development of new aircraft. HFIX uses five domains of possible intervention sources (organizational/administrative, human/crew, technology/engineering, task/ mission, and operational/physical environment) and uses them to guide brainstorming sessions conducted by a group of aviation professionals from varied backgrounds. Once ideas are generated, they are compared and evaluated based of the criteria of feasibility, acceptability, cost, effectiveness, and sustainability. The HFIX domains of possible intervention sources were found lacking and two other sources of intervention strategies were considered: human systems integration (HSI) and doctrine, organization, training, material, leadership, personnel, and facilities (DOTMLPF). Analyzing the merits of each, an alternative list of mishap intervention domains that draws upon the advantages of each was presented. These domains were: mission, manpower, personnel, training, human factors engineering, policy/procedures, leadership, and facilities/environment. Additionally, the original form of HFIX only addresses mishap causes at the acts level of HFACS. Although mishap investigations tend to cite causal errors at this level, the second analytical effort suggests that higher levels such as preconditions, supervision, and organization should also be considered. In the revised version of HFIX all twenty categories of DoD-HFACS were open to scrutiny.

B. RECOMMENDATIONS AND FURTHER RESEARCH

The examination of Naval Safety Center mishap data and CNAF strategic human factors review data revealed an interesting disparity in leading human factors concerns. While mishap investigations tended to identify human errors at the acts level of DoD-HFACS, the CNAF data tended to identify higher levels such as organizational, supervisory, and preconditions. This difference suggests that mishap investigations are not necessarily the most accurate predictor of the causes of future mishaps. Continued research in this area should explore the relative ability of mishap investigations and operator surveys to predict future mishaps. For the Naval Safety Center, it is suggested that aircrew surveys that use the DoD-HFACS taxonomy as a coding scheme can be a helpful source in identifying future mishap causes and developing intervention strategies.

The revised HFIX methodology presented in this thesis is intended to provide a framework for developing effective interventions across a number of organizational levels within the DoD. Individual squadrons that have identified human factors concerns could use it to improve their local safety programs as an element of their required quarterly human factors board. The Naval Safety Center could also benefit from using this methodology to address mishaps in aviation and other communities. Finally, DoD acquisition program managers could use this methodology as part of a comprehensive human factors safety evaluation for a future system. Further study should validate the application of this revised version of HFIX in these various areas.

C. CONCLUSION

The cost of mishaps to the DoD in terms of personnel, equipment, and financial resources continues to be a driving factor in the pursuit of reducing aviation mishap rates. Although technological and engineering improvements have drastically reduced the frequency of mishaps over the last 30 years, the remaining constant is human error. It is unlikely human error will ever be eliminated as a mishap casual factor. However, the effective application of the eight mishap intervention domains (mission, manpower, personnel, training, human factors engineering, policy/procedures, leadership, and facilities/ environment) may be able to reduce its influence. The multidisciplinary approach of HSI is useful in comparing the relative merit of various intervention strategies and performing tradeoffs in order to arrive at an acceptable solution. The revised HFIX methodology draws upon this approach to provide a comprehensive approach to mishap intervention.

APPENDIX. DOD-HFACS NANOCODES

Acts

Are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situation.

Errors (AExxx)

Are factors in a mishap when mental or physical activities of the operator fail to achieve their intended outcome as a result of skill-based, perceptual, or judgment and decision making errors leading to an unsafe situation. Errors are unintended.

Skill-Based Errors (AE1xx)

Are factors in a mishap when errors occur in the operator's execution of a routine, highly practiced task relating to procedure, training or proficiency and result in an unsafe a situation.

AE101 Inadvertent Operation

Inadvertent Operation is a factor when individual's movements inadvertently activate or deactivate equipment, controls or switches when there is no intent to operate the control or device. This action may be noticed or unnoticed by the individual.

AE102 Checklist Error

Checklist Error is a factor when the individual, either through an act of commission or omission makes a checklist error or fails to run an appropriate checklist and this failure results in an unsafe situation.

AE103 Procedural Error

Procedural Error is a factor when a procedure is accomplished in the wrong sequence or using the wrong technique or when the wrong control or switch is used. This also captures errors in navigation, calculation or operation of automated systems.

AE104 Overcontrol/ Undercontrol
Overcontrol/Undercontrol is a factor when an individual responds inappropriately to conditions by either overcontroling or undercontroling the aircraft/vehicle/system. The error may be a result of preconditions or a temporary failure of coordination.

AE105 Breakdown in Visual Scan
Breakdown in Visual Scan is a factor when the individual fails to effectively execute learned/practiced internal or external visual scan patterns leading to unsafe situation.

AE106 Inadequate Anti-G Straining Maneuver
Inadequate Anti-G Straining Maneuver is a factor when the individuals AGSM is improper, inadequate, poorly timed or non-existent and this leads to adverse neurocirculatory effects.

Judgment and Decision-Making Errors (AE2xx)
Are factors in a mishap when behavior or actions of the individual proceed as intended yet the chosen plan proves inadequate to achieve the desired end-state and results in an unsafe situation.

AE201 Risk Assessment – During Operation
Risk Assessment – During Operation is a factor when the individual fails to adequately evaluate the risks associated with a particular course of action and this faulty evaluation leads to inappropriate decision and subsequent unsafe situation. This failure occurs in real-time when formal risk-assessment procedures are not possible.

AE202 Task Misprioritization
Task Misprioritization is a factor when the individual does not organize, based on accepted prioritization techniques, the tasks needed to manage the immediate situation.

AE203 Necessary Action – Rushed
Necessary Action – Rushed is a factor when the individual takes the necessary action as dictated by the situation but performs these actions too quickly and the rush in taking action leads to an unsafe situation.

AE204 Necessary Action – Delayed
Necessary Action – Delayed is a factor when the individual selects a course of action but elects to delay execution of the actions and the delay leads to an unsafe situation.

AE205 Caution/Warning – Ignored
Caution/Warning – Ignored is a factor when a caution or warning is perceived and understood by the individual but is ignored by the individual leading to an unsafe situation.

AE206 Decision-Making During Operation
Decision-Making During Operation is a factor when the individual through faulty logic selects the wrong course of action in a time-constrained environment.

Perception Errors (AE3xx)
Are factors in a mishap when misperception of an object, threat or situation, (such as visual, auditory, proprioceptive, or vestibular illusions, cognitive or attention failures, etc), results in human error.

AE301 Error due to Misperception
Error due to Misperception is a factor when an individual acts or fails to act based on an illusion; misperception or disorientation state and this act or failure to act creates an unsafe situation.

Violations (AVxxx)
Are factors in a mishap when the actions of the operator represent willful disregard for rules and instructions and lead to an unsafe situation. Violations are deliberate.

AV001 Violation - Based on Risk Assessment
Violation- Based on Risk Assessment is a factor when the consequences/risk of violating published procedures was recognized, consciously assessed and honestly determined by
the individual, crew or team to be the best course of action. Routine “work-arounds” and unofficial procedures that are accepted by the community as necessary for operations are also captured under this code.

AV002 Violation - Routine/Widespread
Violation - Routine/Widespread is a factor when a procedure or policy violation is systemic in a unit/setting and not based on a risk assessment for a specific situation. It needlessly

commits the individual, team, or crew to an unsafe course-of-action. These violations may have leadership sanction and may not routinely result in disciplinary/administrative action. Habitual violations of a single individual or small group of individuals within a unit can constitute a routine/widespread violation if the violation was not routinely disciplined or was condoned by supervisors. These violations may also be referred to as "Routine Violations."

AV003 Violation - Lack of Discipline
Violation - Lack of Discipline is a factor when an individual, crew or team intentionally violates procedures or policies without cause or need. These violations are unusual or isolated to specific individuals rather than larger groups. There is no evidence of these violations being condoned by leadership. These violations may also be referred to as "exceptional violations." (NOTE: These violations may also carry UCMJ consequences. Boards should consult the Judge Advocate of the convening authority.)

Preconditions
Are factors in a mishap if active and/or latent preconditions such as conditions of the operators, environmental or personnel factors affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

Environmental Factors (PExxx)
Are factors in a mishap if *physical* or *technological* factors affect practices, conditions and actions of individual and result in human error or an unsafe situation.

Physical Environment (PE1xx)
Are factors in a mishap if environmental phenomena such as weather, climate, white out or brown out conditions affect the actions of individuals and result in human error or an unsafe situation.

PE101 Vision Restricted by Icing/Windows Fogged/Etc
Vision Restricted by Icing/Windows Fogged/Etc is a factor when it is determined by the investigator that icing or fogging of the windshield/windscreen or canopy restricted the vision of the individual to a point where normal duties were affected.

PE102 Vision Restricted by Meteorological Conditions
Vision Restricted by Meteorological Conditions is a factor when weather, haze, or darkness restricted the vision of the individual to a point where normal duties were affected.

PE103 Vibration
Vibration is a factor when the intensity or duration of the vibration is sufficient to cause impairment of vision or adversely effect the perception of orientation.

PE104 Vision Restricted in Workspace by Dust/Smoke/Etc.
Vision restricted in workspace by dust/smoke/etc. is a factor when dust, smoke, etc. inside the cockpit, vehicle or workstation restricted the vision of the individual to a point where normal duties were affected.

PE105 Windblast
Windblast is a factor when the individual's ability to perform required duties is degraded during or after exposure to a windblast situation.

PE106 Thermal Stress – Cold
Thermal Stress – Cold is a factor when the individual is exposed to cold resulting in compromised function.

PE107 Thermal Stress – Heat
Thermal Stress – Heat is a factor when the individual is exposed to heat resulting in compromised function.

PE108 Maneuvering Forces – In-Flight
Maneuvering Forces – In-Flight is a factor when acceleration forces of longer than one second cause injury, prevent or interfere with the performance of normal duties. Do not
use this code to capture G-induced loss of consciousness

PE109 Lighting of Other Aircraft/Vehicle
Lighting of Other Aircraft/Vehicle is a factor when the absence, pattern, intensity or location of the lighting of other aircraft/vehicle prevents or interferes with safe task accomplishment.

PE110 Noise Interference
Noise Interference is a factor when any sound not directly related to information needed for task accomplishment interferes with the individual's ability to perform that task.

PE111 Brownout/Whiteout
Brownout/Whiteout is a factor when dust, snow, water, ash or other particulates in the environment are disturbed by the aircraft, vehicle or person and cause a restriction of vision to a point where normal duties are affected.

Technological Environment (PE2xx)
Are factors in a mishap when cockpit/vehicle/control station/ workspace design factors or automation affect the actions of individuals and result in human error or an unsafe situation.

PE201 Seating and Restraints
Seating and Restraints is a factor when the design of the seat or restraint system, the ejection system, seat comfort or poor impact-protection qualities of the seat create an unsafe situation.

PE202 Instrumentation and Sensory Feedback Systems
Instrumentation and Sensory Feedback Systems is a factor when instrument factors such as design, reliability, lighting, location, symbology or size are inadequate and create an unsafe situation. This includes NVDs, HUD, off-bore-site and helmet-mounted display systems and inadequacies in auditory or tactile situational awareness or warning systems such as aural voice warnings or stick shakers.

PE203 Visibility Restrictions
Visibility Restrictions is a factor when the lighting system, windshield/windscreen/canopy design, or other obstructions prevent necessary visibility and create an unsafe situation. This includes glare or reflections on the canopy/windscreen/ windshield. Visibility restrictions due to weather or environmental conditions are captured under PE101 or PE102.

PE204 Controls and Switches
Controls and Switches is a factor when the location, shape, size, design, reliability, lighting or other aspect of a control or switch is inadequate and this leads to an unsafe situation.

PE205 Automation
Automation is a factor when the design, function, reliability, use guidance, symbology, logic or other aspect of automated systems creates an unsafe situation.

PE206 Workspace Incompatible with Human
Workspace Incompatible with Human is a factor when the workspace is incompatible with the mission requirements and mission safety for this individual.

PE207 Personal Equipment Interference
Personal Equipment Interference is a factor when the individual's personal equipment interferes with normal duties or safety.

PE208 Communications – Equipment
Communications - Equipment is a factor when comm. equipment is inadequate or unavailable to support mission demands. (i.e., aircraft/vehicle with no intercom) This includes electronically or physically blocked transmissions. Communications can be voice, data or multi-sensory.

Condition of Individuals (PCxxx)
Are factors in a mishap if cognitive, psycho-behavioral, adverse physical state, or physical/mental limitations affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

Cognitive Factors (PC1xx)
Are factors in a mishap if cognitive or attention management conditions affect the perception or performance of individuals and result in human error or an unsafe situation.

PC101 Inattention
Inattention is a factor when the individual has a state of reduced conscious attention due to a sense of security, self-confidence, boredom or a perceived absence of threat from the environment which degrades crew performance. (This may often be a result of highly repetitive tasks. Lack of a state of alertness or readiness to process immediately available information.)

PC102 Channelized Attention
Channelized Attention is a factor when the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a

subjectively equal or higher or more immediate priority, leading to an unsafe situation. May be
described as a tight focus of attention that leads to the exclusion of comprehensive situational information.

PC103 Cognitive Task Oversaturation
Cognitive Task Oversaturation is a factor when the quantity of information an individual must process exceeds their cognitive or mental resources in the amount of time available to process the information.

PC104 Confusion
Confusion is a factor when the individual is unable to maintain a cohesive and orderly awareness of events and required actions and experiences a state characterized by bewilderment, lack of clear thinking, or (sometimes) perceptual disorientation.

PC105 Negative Transfer
Negative Transfer is a factor when the individual reverts to a highly learned behavior used in a previous system or situation and that response is inappropriate or degrades mission performance.

PC106 Distraction
Distraction is a factor when the individual has an interruption of attention and/or inappropriate redirection of attention by an environmental cue or mental process that degrades performance.

PC107 Geographic Misorientation (Lost)
Geographic Misorientation (Lost) is a factor when the individual is at a latitude and/or longitude different from where he believes he is or at a lat/long unknown to the individual and this creates an unsafe situation.

PC108 Checklist Interference
Checklist Interference is a factor when an individual is performing a highly automated/learned task and is distracted by anther cue/event that results in the interruption and subsequent failure to complete the original task or results in skipping steps in the original task.

Psycho-Behavioral Factors (PC2xx)
Are factors when an individual's personality traits, psychosocial problems, psychological disorders or inappropriate motivation creates an unsafe situation.

PC201 Pre-Existing Personality Disorder
Pre-existing Personality Disorder is a factor when a qualified professional determines the individual met Diagnostic and Statistical Manual criteria for a personality disorder.

PC202 Pre-Existing Psychological Disorder
Pre-existing Psychological Disorder is a factor when a qualified professional determines the individual met Diagnostic and Statistical Manual criteria for a psychological disorder.

PC203 Pre-Existing Psychosocial Problem
Pre-existing Psychosocial Problem is a factor when a qualified professional determines the individual met Diagnostic and Statistical Manual criteria for a psychosocial problem.

PC204 Emotional State
Emotional State is a factor when the individual is under the influence of a strong positive or negative emotion and that emotion interferes with duties.

PC205 Personality Style
Personality style is a factor when the individual's personal interaction with others creates an unsafe situation. Examples are authoritarian, over-conservative, impulsive, invulnerable, submissive or other personality traits that result in degraded crew performance.

PC206 Overconfidence
Overconfidence is a factor when the individual overvalues or overestimates personal capability, the capability of others or the capability of aircraft/vehicles or equipment and this creates an unsafe situation.

PC207 Pressing
Pressing is a factor when the individual knowingly commits to a course of action that presses them and/or their equipment beyond reasonable limits.

PC208 Complacency
Complacency is a factor when the individual's state of reduced conscious attention due to an attitude of overconfidence, undermotivation or the sense that others "have the situation under control" leads to an unsafe situation.

PC209 Inadequate Motivation
Motivation – Inadequate is a factor when the individual's motivation to accomplish a task or mission is weak or indecisive.

PC210 Misplaced Motivation
Misplaced Motivation is a factor when an individual or unit replaces the primary goal of a mission with a personal goal.

PC211 Overaggressive
Overaggressive is a factor when an individual or crew is excessive in the manner in which they conduct a mission.

PC212 Excessive Motivation to Succeed
Motivation to Succeed – Excessive is a factor when the individual is preoccupied with success to the exclusion of other mission factors leading to an unsafe situation.

PC213 Get-Home-Itis/Get-There-Itis
Get-Home-Itis/Get-There-Itis is a factor when an individual or crew is motivated to complete a mission or reach a destination for personal reasons, thereby short cutting necessary procedures or exercising poor judgment, leading to an unsafe situation.

PC214 Response Set
Response set is a factor when the individual has a cognitive or mental framework of expectations that predispose them to a certain *course of action* regardless of other cues.

PC215 Motivational Exhaustion (Burnout)
Motivational Exhaustion (Burnout) is a factor when the individual has the type of exhaustion associated with the wearing effects of high operations and personal tempo where their operational requirements impinge on their ability to satisfy their personal requirements and leads to degraded cognitive or operational capability.

Adverse Physiological States (PC3xx)
Are factors when an individual experiences a physiologic event that compromises human performance and this decreases performance and results in an unsafe situation.

PC301 Effects of G Forces (G-LOC, etc)
Effects of G Forces (G-LOC, etc) is a factor when the individual experiences G-induced loss of consciousness (GLOC), greyout, blackout or other neuro-circulatory affects of sustained acceleration forces.

PC302 Prescribed Drugs
Prescribed Drugs is a factor when the individual uses a prescribed drug with measurable effect interfering with performance.

PC303 Operational Injury/Illness
Operational Injury/Illness is a factor when an injury is sustained or illness develops from the operational environment or *during* the mission and this injury or illness results in an unsafe situation. This includes toxic exposure. Details of injury, illness or toxic exposure should be captured in the medical investigation. Do not use this code to capture injury or illness that does not cause an unsafe situation or contribute to the mishap sequence.

PC304 Sudden Incapacitation/Unconsciousness
Sudden Incapacitation/Unconsciousness is a factor when the individual has an abrupt loss of functional capacity/ conscious awareness. (NOT GLOC) Capture medical causes for the incapacitation in the AFSAS medical module.

PC305 Pre-Existing Physical Illness/Injury/Deficit
Pre-Existing Physical llness/Injury/Deficit is a factor when a physical illness, injury or eficit that existed at the time the individual boarded the aircraft or began the ission/task causes an unsafe situation. This includes situations where wavered physical defects contribute to an unsafe situation and situations where vision deficit or loss of prosthetic devices during the mission cause an unsafe situation. An individual must board the aircraft or begin the mission/task with prior knowledge of illness/injury/deficit otherwise mark and rate PC303. Details of injury, illness or deficit should be captured in the medical investigation. Do not use this code to capture injury or illness that does not cause an unsafe

situation or contribute to the mishap sequence. (i.e., medevac patient whose condition deteriorates during flight).

PC306 Physical Fatigue (Overexertion)
Physical Fatigue (Overexertion) is a factor when the individual's diminished physical capability is due to overuse (time/relative load) and it degrades task performance. (The effects of prolonged physical activity, or the effects of brief but relatively extreme physical activity, either of which taxes a person's physical endurance or strength beyond the individual's normal limits.)

PC307 Fatigue - Physiological/Mental
Fatigue - Physiological/Mental is a factor when the individual's diminished physical or mental capability is due to an inadequate recovery, as a result of restricted or shortened sleep or physical or mental activity during prolonged wakefulness. Fatigue may additionally be described as acute, cumulative or chronic.

PC308 Circadian Rhythm Desynchrony
Circadian Rhythm Desynchrony is a factor when the individual's normal, 24-hour rhythmic biological cycle (circadian rhythm) is disturbed and it degrades task performance. This is caused typically by night work or rapid movement (such as one time zone per hour) across several time zones. Referred to as "shift lag" and "jet lag." (Time in the new time zone will lead to adaptation and recovery; the amount of time depends on the number of time zones crossed and the direction of travel. Recovery from shift lag may never occur.)

PC309 Motion Sickness
Motion Sickness is a factor when the symptoms of motion sickness impair normal performance. Motion sickness symptoms include nausea, sweating, flushing, vertigo, headache, stomach awareness, malaise, and vomiting.

PC310 Trapped Gas Disorders
Trapped Gas Disorders are a factor when gasses in the middle ear, sinuses, teeth, or intestinal tract expand or contract on ascent or descent causing an unsafe situation. Also capture alternobaric vertigo under this code. If the alternobaric vertigo induces spatial disorientation you must mark and rate PC508, PC509 or PC510.

PC311 Evolved Gas Disorders
Evolved gas disorders are a factor when inert-gas evolves in the blood causing an unsafe situation. This includes, chokes, CNS, bends or parasthesias or other conditions caused by inert-gas evolution.

PC312 Hypoxia
Hypoxia is a factor when the individual has insufficient oxygen supply to the body sufficient to cause an impairment of function.

PC313 Hyperventilation
Hyperventilation is a factor when the effect of ventilating above the physiological demands of the body causes the individual's performance capabilities to be degraded.

PC314 Visual Adaptation
Visual Adaptation is a factor when the normal human limitation of dark-adaptation rate affects safety, for example, when transitioning between aided and unaided night vision.

PC315 Dehydration
Dehydration is a factor when the performance of the operator is degraded due to dehydration as a result of excessive fluid losses due to heat stress or due to insufficient fluid intake.

PC316 Physical Task Oversaturation
Physical Task Oversaturation is a factor when the number or complexity of manual tasks in a compressed time period exceeds an individual's capacity to perform.

Physical/Mental Limitations (PC4xx)
Are factors in a mishap when an individual, temporarily or permanently lacks the physical or mental capabilities to cope with a situation and this insufficiency causes an unsafe situation.

PC401 Learning Ability/Rate
Learning Ability – Rate is a factor when the individual's relative efficiency with which new information is acquired, and relatively permanent adjustments made in behavior or thinking, are not consistent with mission demands.

PC402 Memory Ability/Lapses
Memory Ability/Lapses is a factor when the individual is unable or has lapses in the ability to recall past experience

needed for safe mission completion. (experience includes any information a person receives through any means, any cognitive functions he or she performed on that information, and any response he or she made as a result of it.)

PC403 Anthropometric/Biomechanical Limitations
Anthropometric/Biomechanical limitations are a factor when the size, strength, dexterity, mobility or other biomechanical limitations of an individual creates an unsafe situation. It must be expected that the average individual qualified for that duty position could accomplish the task in question.

PC404 Motor Skill/Coordination or Timing Deficiency
Motor Skill/Coordination or Timing Deficiency is a factor when the individual lacks the required psychomotor skills, coordination or timing skills necessary to accomplish the task attempted.

PC405 Technical/Procedural Knowledge
Technical/Procedural Knowledge is a factor when an individual was adequately exposed to the information needed to perform the mission element but did not absorb it. Lack of knowledge implies no deficiency in the training program, but rather the failure of the individual to absorb or retain the information. (Exposure to information at a point in the past does not imply "knowledge" of it.)

Perceptual Factors (PC5xx)
Are factors in a mishap when misperception of an object, threat or situation, (visual, auditory, proprioceptive, or vestibular conditions) creates an unsafe situation.

PC501 Illusion – Kinesthetic
Illusion – Kinesthetic is a factor when somatosensory stimuli of the ligaments, muscles, or joints cause the individual to have an erroneous perception of orientation, motion or acceleration leading to degraded performance. (If this illusion leads to spatial disorientation you must mark and rate PC508, PC509 or PC510.)

PC502 Illusion – Vestibular
Illusion – Vestibular is a factor when stimuli acting on the semicircular ducts or otolith organs of the vestibular apparatus cause the individual to have an erroneous

perception of orientation, motion or acceleration leading to degraded performance. (If this illusion leads to spatial disorientation you must mark and rate PC508, PC509 or PC510.)

PC503 Illusion – Visual
Illusion – Visual is a factor when visual stimuli result in an erroneous perception of orientation, motion or acceleration, leading to degraded performance. (If this illusion leads to spatial disorientation you must mark and rate PC508, PC509 or PC510.)

PC504 Misperception of Operational Conditions
Misperception of Operational Conditions is a factor when an individual misperceives or misjudges altitude, separation, speed, closure rate, road/sea conditions, aircraft/vehicle location within the performance envelope or other operational conditions and this leads to an unsafe situation.

PC505 Misinterpreted/Misread Instrument
Misinterpreted/Misread Instrument is a factor when the individual is presented with a correct instrument reading but its significance is not recognized, it is misread or is misinterpreted.

PC506 Expectancy
Expectancy is a factor when the individual's expects to perceive a certain reality and those expectations are strong enough to create a *false perception* of the expectation.

PC507 Auditory Cues
Auditory Cues is a factor when the auditory inputs are correctly interpreted but are misleading or disorienting. Also when the inputs are incorrectly interpreted and cause an impairment of normal performance.

PC508 Spatial Disorientation (Type 1) Unrecognized
Spatial Disorientation is a failure to correctly sense a position, motion or attitude of the aircraft or of oneself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical. Spatial Disorientation (Type 1) Unrecognized is a factor when a person's cognitive awareness of one or more of the following varies from

reality: attitude; position; velocity; direction of motion or acceleration. Proper control inputs are not made because the need is unknown.

PC509 Spatial Disorientation (Type 2) Recognized
Spatial Disorientation is a failure to correctly sense a position, motion or attitude of the aircraft or of oneself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical. Spatial Disorientation (Type 2) is a factor when recognized perceptual confusion is induced through one or more of the following senses: visual; vestibular; auditory; tactile; proprioception or kinesthetic. Proper control inputs are still possible.

PC510 Spatial Disorientation (Type 3) Incapacitating
Spatial Disorientation is a failure to correctly sense a position, motion or attitude of the aircraft or of oneself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical. Spatial Disorientation (Type 3) Incapacitating is a factor when an individual is unable to make proper control inputs for safe operation of the aircraft or system due to a conflict (often extreme) between the sensory systems identified in type 2.

PC511 Temporal Distortion
Temporal Distortion is a factor when the individual experiences a compression or expansion of time relative to reality leading to an unsafe situation. (Often associated with a "fight or flight" response.)

Personnel Factors (PPxxx)
Are factors in a mishap if self imposed stressors or crew resource management affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

Coordination/Communication/Planning Factors(PP1xx)
Refer to interactions among individuals, crews, and teams involved with the preparation and execution of a mission that resulted in human error or an unsafe situation.

PP101 Crew/Team Leadership
Crew/Team Leadership is a factor when the crew/team leadership techniques failed to facilitate a proper crew climate, to include establishing and maintaining an accurate

and shared understanding of the evolving mission and plan on the part of all crew or team members.

PP102 Cross-Monitoring Performance
Cross-monitoring performance is a factor when crew or team members failed to monitor, assist or back-up each other's actions and decisions.

PP103 Task Delegation
Task delegation is a factor when the crew or team members failed to actively manage the distribution of mission tasks to prevent the overloading of any crewmember.

PP104 Rank/Position Authority Gradient
Rank/position authority gradient is a factor when the differences in rank of the team, crew or flight caused the mission performance capabilities to be degraded. Also conditions where formal or informal authority gradient is too steep or too flat across a crew, team or flight and this condition degrades collective or individual performance.

PP105 Assertiveness
Assertiveness is a factor when individuals failed to state critical information or solutions with appropriate persistence.

PP106 Communicating Critical Information
Communicating critical information is a factor when known critical information was not provided to appropriate individuals in an accurate or timely manner.

PP107 Standard/Proper Terminology
Standard/proper terminology is a factor when clear and concise terms, phrases hand signals, etc per service standards and training were not used.

PP108 Challenge and Reply
Challenge and reply is a factor when communications did not include supportive feedback or acknowledgement to ensure that personnel correctly understand announcements or directives.

PP109 Mission Planning
Mission planning is a factor when an individual, crew or team failed to complete all preparatory tasks associated with planning the mission, resulting in an unsafe situation.

Planning tasks include information collection and analysis, coordinating activities within the crew or team and with appropriate external agencies, contingency planning, and risk assessment.

PP110 Mission Briefing
Mission briefing is a factor when information and instructions provided to individuals, crews, or teams were insufficient, or participants failed to discuss contingencies and strategies to cope with contingencies.

PP111 Task/Mission-In-Progress Re-Planning
Task/mission-in-progress re-planning is a factor when crew or team members fail to adequately reassess changes in their dynamic environment during mission execution and change their mission plan accordingly to ensure adequate management of risk.

PP112 Miscommunication
Miscommunication is a factor when correctly communicated information is misunderstood, misinterpreted, or disregarded.

Self-Imposed Stress (PP2xx)
Is a factor in a mishap if the operator demonstrates disregard for rules and instructions that govern the individuals readiness to perform, or exhibits poor judgment when it comes to readiness and results in human error or an unsafe situation.

PP201 Physical Fitness
Physical Fitness is a factor when the relative physical state of the individual, in terms of a regular rigorous exercise program or a physically active lifestyle, is not adequate to support mission demands.

PP202 Alcohol
Alcohol is a factor when the acute or residual effects of alcohol impaired performance or created an unsafe situation.

PP203 Drugs/Supplements/Self medication
Drugs/Supplements/Self-medication is a factor when the individual takes any drug, other than prescribed, that interferes with performance. This includes nicotine or caffeine in sufficient quantities to cause impairment of normal function. This also includes any chemical compound taken for purposes of prevention of disease, treatment of

disease, weight management, mood alteration, birth control or sleep management, etc. The effects may be direct or residual. Alcohol is captured under PP206.

PP204 Nutrition
Nutrition is a factor when the individual's nutritional state or poor dietary practices are inadequate to fuel the brain and body functions resulting in degraded performance.

PP205 Inadequate Rest
Inadequate rest is a factor when the opportunity for rest was provided but the individual failed to take the opportunity to rest.

PP206 Unreported Disqualifying Medical Condition
Unreported Disqualifying Medical Condition is a factor when the operator intentionally operates/flies with a known disqualifying medical condition that results in an unsafe situation.

Supervision
Is a factor in a mishap if the methods, decisions or policies of the supervisory chain of command directly affect practices, conditions, or actions of individual and result in human error or an unsafe situation.

Inadequate Supervision (SIxxx)
Is a factor in a mishap when supervision proves inappropriate or improper and fails to identify hazard, recognize and control risk, provide guidance, training and/or oversight and results in human error or an unsafe situation.

SI001 Leadership/Supervision/Oversight Inadequate
Leadership/Supervision/Oversight Inadequate is a factor when the availability, competency, quality or timeliness of leadership, supervision or oversight does not meet task demands and creates an unsafe situation. Inappropriate supervisory pressures are also captured under this code.

SI002 Supervision – Modeling
Supervision – Modeling is a factor when the individual's learning is influenced by the behavior of peers and supervisors and when that learning manifests itself in actions that are either inappropriate to the individual's skill level or violate standard procedures and lead to an unsafe situation.

SI003 Local Training Issues/Programs
Local Training Issues/Programs are a factor when one-time or recurrent training programs, upgrade programs, transition programs or any other local training is inadequate or unavailable (etc) and this creates an unsafe situation. (Note: the failure of an individual to absorb the training material in an adequate training program does not indicate a training program problem. Capture these factors under PC401 “learning ability/rate” or PC405 “Technical/Procedural Knowledge.” The failure of an individual to recall learned information under stress or while fatigued despite attending an adequate training program does not indicate a training program problem. Capture these factors under PC402 “Memory/ Ability lapses” or other cognitive factors such as PC104 “Confusion,” PC106 “Distraction,” PC105 “Negative Transfer,” etc.)

SI004 Supervision – Policy
Supervision – Policy is a factor when policy or guidance or lack of a policy or guidance leads to an unsafe situation.

SI005 Supervision – Personality Conflict
Supervision – Personality Conflict is a factor when a supervisor and individual member experience a "personality conflict" that leads to a dangerous error in judgment/action.

SI006 Supervision – Lack of Feedback
Supervision – Lack of Feedback is a factor when information critical to a potential safety issue had been provided to supervisory or management personnel without feedback to the source (failure to close the loop).

Planned Inappropriate Operations (SPxxx)
Is a factor in a mishap when supervision fails to adequately assess the hazards associated with an operation and allows for unnecessary risk. It is also a factor when supervision allows non-proficient or inexperienced personnel to attempt missions beyond their capability or when crew or flight makeup is inappropriate for the task or mission.

SP001 Ordered/Led on Mission Beyond Capability
Ordered/Led on Mission Beyond Capability is a factor when supervisor/management directs personnel to undertake a mission beyond their skill level or beyond the capabilities of their equipment.

SP002 Crew/Team/Flight Makeup/Composition
Crew/Team/Flight Makeup/Composition is a factor when, in the opinion of the investigator, the makeup of the crew or of the flight should have reasonably raised obvious safety concerns in the minds of crewmembers involved in the mission, or in any other individual directly related to the scheduling of this mission.

SP003 Limited Recent Experience
Limited Recent Experience is a factor when the supervisor selects an individual who's experience for either a specific maneuver, event or scenario is not sufficiently current to permit safe mission execution.

SP004 Limited Total Experience
Limited Total Experience is a factor when a supervisor selects an individual who's individual has performed a maneuver, or participated in a specific scenario, infrequently or rarely.

SP005 Proficiency
Proficiency is a factor when and individual is not proficient in a task, mission or event.

SP006 Risk Assessment – Formal
Risk Assessment – Formal is a factor when supervision does not adequately evaluate the risks associated with a mission or when pre-mission risk assessment tools or risk assessment programs are inadequate.

SP007 Authorized Unnecessary Hazard
Authorized Unnecessary Hazard is a factor when supervision authorizes a mission or mission element that is unnecessarily hazardous without sufficient cause or need. Includes intentionally scheduling personnel for mission or operation that they are not qualified to perform.

Failure to Correct Known Problem (SFxxx)
Is a factor in a mishap when supervision fails to correct known deficiencies in documents, processes or procedures, or fails to correct inappropriate or unsafe actions of individuals, and this lack of supervisory action creates an unsafe situation.

SF001 – Personnel Management
Personnel management is a factor when a supervisor fails to identify an operator or aviator who exhibits recognizable risky behaviors or unsafe tendencies or fails to institute remedial actions when an individual is identified with risky behaviors or unsafe tendencies.

SF002 – Operations Management
Operations management is a factor when a supervisor fails to correct known hazardous practices, conditions or guidance that allows for hazardous practices within the scope of his/her command.

Supervisory Violations (SVxxx)
Is a factor in a mishap when supervision while managing organizational assets willfully disregards instructions, guidance, rules, or operating instructions and this lack of supervisory responsibility creates an unsafe situation.

SV001 Supervision – Discipline Enforcement (Supervisory act of omission)
Supervision – Discipline Enforcement is a factor when unit (organizational) and operating rules have not been enforced by the normally constituted authority.

SV002 Supervision – Defacto Policy
Supervision – Defacto Policy is a factor when unwritten or “unofficial” policy perceived and followed by the individual, which has not been formally established by the properly constituted authority, leads to an unsafe situation.

SV003 Directed Violation
Directed Violation is a factor when a supervisor directs a subordinate to violate existing regulations, instructions or technical guidance.

SV004 Currency
Currency is a factor when an individual has not met the general training requirements for his job/weapon system and is considered “non-current” and supervision/leadership inappropriately allows the individual to perform the mission element for which the individual is non-current.

Organizational Influences
Are factors in a mishap if the communications, actions, omissions or policies of upper-level management directly or indirectly affect supervisory practices, conditions or actions of the operator(s) and result in system failure, human error or an unsafe situation.

Resource/Acquisition Management (ORxxx)
Is a factor in a mishap if resource management and/or acquisition processes or policies, directly or indirectly, influence system safety and results in poor error management or creates an unsafe situation.

OR001 Air Traffic Control Resources
Air Traffic Control Resources is a factor when inadequate monitoring of airspace, enroute nav-aids or language barriers in air traffic controllers cause an unsafe situation. Note: If the unsafe acts of an individual air traffic controller are determined to be a factor in a mishap then the controller must be added and investigated as a mishap person.

OR002 Airfield Resources
Airfield Resources are a factor when runways, taxiways, ramps, terminal ATC resources or nav-aids, lighting systems, SOF/RSU resources or the environment surrounding the airfield are inadequate or unsafe. If the airfield or environment created a visual illusion that contributed to the mishap sequence you must also mark and rate PC503 “Illusion - Visual.”

OR003 Operator Support
Operator Support is a factor when support facilities (dining, exercise, quarters, medical care, etc) or opportunity for recreation or rest are not available or adequate and this creates an unsafe situation. This includes situations where leave is not taken for reasons other than the individual’s choice.

OR004 Acquisition Policies/Design Processes
Acquisition Policies/Design Processes is a factor when the processes through which aircraft, vehicle, equipment or logistical support are acquired allows inadequacies or when design deficiencies allow inadequacies in the acquisition and the inadequacies create an unsafe situation.

OR005 Attrition Policies
Attrition Policies is a factor when the process through which equipment is removed from service is inadequate and this inadequacy creates an unsafe situation**.**

OR006 Accession/Selection Policies
Accession/Selection Policies is a factor when the process through which individuals are screened, brought into the service or placed into specialties is inadequate and creates an unsafe situation.

OR007 Personnel Resources
Personnel Resources is a factor when the process through which manning, staffing or personnel placement or manning resource allocations are inadequate for mission demands and the inadequacy causes an unsafe situation.

OR008 Informational Resources/Support
Informational Resources/Support is a factor when weather, intelligence, operational planning material or other information necessary for safe operations planning are not available.

OR009 Financial Resources/Support
Financial Resources/Support is a factor when an organization or operation does not receive the financial resources to complete its assigned mission and this deficiency creates an unsafe situation.

Organizational Climate (OCxxx)
Is a factor in a mishap if organizational variables including environment, structure, policies, and culture influence individual actions and results in human error or an unsafe situation.

OC001 Unit/Organizational Values/Culture
Unit/Organizational Values/Culture is a factor when explicit/implicit actions, statements or attitudes of unit leadership set unit/organizational values (culture) that allow an environment where unsafe mission demands or pressures exist.

OC002 Evaluation/Promotion/Upgrade
Evaluation/Promotion/Upgrade is a factor when an individual perceives that their performance on a task will inappropriately impact an evaluation, promotion or

opportunity for upgrade and this pressure creates an unsafe situation. Other inappropriate supervisory pressures are captured under SI001 Supervision – Inadequate.

OC003 Perceptions of Equipment
Perceptions of Equipment is a factor when over or under confidence in an aircraft, vehicle, device, system or any other equipment creates an unsafe situation.

OC004 Unit Mission/Aircraft/Vehicle/Equipment Change or Unit Deactivation
Unit Mission/Aircraft/Vehicle/Equipment Change or Unit Deactivation is a factor when the process of changing missions/aircraft/vehicle/equipment or an impending unit deactivation creates an unsafe situation.

OC005 Organizational Structure
Organizational Structure is a factor when the chain of command of an individual or structure of an organization is confusing, non-standard or inadequate and this creates an unsafe situation.

Organizational Processes (OPxxx)
Is a factor in a mishap if organizational processes such as operations, procedures, operational risk management and oversight negatively influence individual, supervisory, and/or organizational performance and results in unrecognized hazards and/or uncontrolled risk and leads to human error or an unsafe situation.

OP001 Ops Tempo/Workload
Ops Tempo/Workload is a factor when the pace of deployments, workload, additional duties, off-duty education, PME, or other workload-inducing condition of an individual or unit creates an unsafe situation.

OP002 Program and Policy Risk Assessment
Program and Policy Risk Assessment is a factor when the potential risks of a large program, operation, acquisition or process are not adequately assessed and this inadequacy leads to an unsafe situation.

OP003 Procedural Guidance/Publications
Procedural Guidance/Publications is a factor when written direction, checklists, graphic depictions, tables, charts or

other published guidance is inadequate, misleading or inappropriate and this creates an unsafe situation.

OP004 Organizational Training Issues/Programs
Organizational Training Issues/Programs are a factor when one-time or initial training programs, upgrade programs, transition programs or other training that is conducted outside the local unit is inadequate or unavailable (etc) and this creates an unsafe situation. (Note: the failure of an individual to absorb the training material in an adequate training program does not indicate a training program problem. Capture these factors under PC401 “Learning Ability/Rate” or PC405 “Technical/Procedural Knowledge.” The failure of an individual to recall learned information under stress or while fatigued despite attending an adequate training program does not indicate a training program problem. Capture these factors under PC402 “Memory/ Ability lapses” or other cognitive factors such as PC104 “Confusion,” PC106 “Distraction,” PC105 “Negative Transfer” or one of the forms of Fatigue, etc.)

OP005 Doctrine
Doctrine is a factor when the doctrine, philosophy or concept of operations in an organization is flawed or accepts unnecessary risk and this flaw or risk acceptance leads to an unsafe situation or uncontrolled hazard.

OP006 Program Oversight/Program Management
Program Oversight/Program Management is a factor when programs are implemented without sufficient support, oversight or planning and this leads to an unsafe situation.

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