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LT COL GIBB RANDALL W

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ARIZONA STATE UNIVERSITY

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Classification of Air Force Aviation Accidents:

Mishap Trends and Prevention

Randy Gibb

Arizona State University

Wes Olson

United States Air Force Academy

Keywords: human error; controlled flight into terrain (CFIT), approach and landing accident (ALA); midair collisions; aviation safety, spatial disorientation, human factors analysis and classification system (HFACS)

Address correspondence to Randy Gibb, Department of Industrial Engineering, Arizona State University, PO Box 875906, Tempe AZ, 85287-5906; randall.gibb@asu.edu

Abstract

This paper re-analyzed 124 United States Air Force aviation Class A mishaps using the new Department of Defense Human Factors Analysis and Classification System (DoD HFACS). DoD HFACS is organized in a hierarchical manner to identify causal factors at the organizational and supervisory level, preconditions for unsafe acts, and the acts themselves. Re-analysis of a sample of mishaps from 1992 – 2005 using the DoD HFACS framework was accomplished to identify mitigation strategies oriented towards the underlying latent errors, not simply the unsafe acts. The analysis suggested intervention that should focus on improvements in Crew Resource Management and Operational Risk Management.

Introduction

In 2003, the Secretary of Defense issued letter titled, "Reducing Preventable Accidents," which challenged the Department of Defense (DoD) to reduce accident rates by 50% in the next two years (Rumsfeld, 2003). General Jumper, the former Chief of Staff of the USAF, stated that the USAF goal is eventually to reach a zero mishap rate, "any goal other than zero implies that some mishaps are acceptable. But no mishap is" (Jumper, 2004, p. 1). As part of the effort to achieve these ambitious targets, the United States Army, Navy, Coast Guard, Marine Corps, and Air Force agreed to adopt a common policy on the collection and analysis of mishap human factors data (Joint Services Safety Chiefs Letter, 2005). This agreement stated that all the services are to incorporate the DoD Human Factors Analysis and Classification System (HFACS) to help mitigate human factors hazards (2005). The DoD HFACS framework was adopted to better understand the precursors and underlying causal human factors associated with mishaps.

The objective of this research is to use the new DoD HFACS to expose trends in USAF accidents that lay further up the chain of events than previous classification systems have been able to find. Then more importantly, use the information to advocate improvements in operations. The concept of going beyond crew actions and inactions is not new. Notable studies involving military aviation (Feggetter, 1982; Gerbert & Kemmler, 1986; Holland & Freeman, 1995; Shappell & Wiegmann, 1996; Yacavone, 1993), military and crew resource management (CRM) research (Nullmeyer, Stella, & Montijo, 2005; Wiegmann & Shappell, 1999), research emphasizing prevention measures (Fitts & Jones, 1961; Khatwa & Helmreich, 1999; Kowalsky, Masters, Stone, Babcock, & Rypka, 1974; Moroze & Snow, 1999), and those specifically addressing HFACS (Shappell & Wiegmann, 2000, 2003; Wiegmann & Shappell, 1997, 2001) greatly relate to the present paper.

The authors re-analyzed previous USAF mishap investigative reports using the DoD HFACS to identify and mitigate prevalent causal human factors. DoD HFACS analyzed a sample of USAF accidents from 1992 – 2005 and specific latent operational hazards were identified. Prevention measures based on those latent hazards are then proposed with the goal of reduced mishap rate to save lives, resources, and money.

USAF Mishap Information

The USAF defines a Class A mishap as one which involves a fatality or permanent disability, destroys an aircraft, or has a total mishap cost in excess of $1 Million (Air Force Safety Analysis [AFSA], 2003, p. 5). The overall USAF average Class A mishap rate for the last 10-year period is 1.32 mishaps every 100,000 flying hours or 1 mishap every 75,757 hours (Air Force Safety, 2005). This rate can be considered the probability of a mishap, or the risk. Put another way, it is the time between failures (TBF), one catastrophic failure every 75,757 flying hours. The goal of this study is to contribute to Class A mishap reduction by mitigating risks at all levels, not just focusing on the actions of the pilot(s).

The following Class A mishaps are highlighted because of their recency. Despite years of CRM and Operational Risk Management (ORM) training and education causal factors representing those constructs still contribute to mishaps today. In August, 2002, an MC-130H special operations aircraft flying a night low-level navigation training mission in a mountainous area of Puerto Rico hit a ridgeline killing all crewmembers on board (Accident Investigation Board [AIB], 2002). The AIB cited a lack of crew lost situational awareness (SA) and the lack of appropriate response to terrain warnings. Other factors contributing to the mishap were overall crew preparation, misdirected attentional focus on the weather, CRM issues, and poor crew judgment (AIB, 2002). A similar accident occurred in March of 2005 when a USAF MC-130H was flying a night training mission in the mountains of Albania and struck the terrain resulting in 9 fatalities (Rolfsen, 2005a). The AIB concluded that the accident did not occur due to avionics or mechanical problems but due to "a series of critical errors by the flight deck crew led to the special operations plane being trapped as it flew too low and too slow in the remote valley" (Rolfsen, 2005a, p. 14). Note both accidents occurred on training missions and were caused at least in part by failures in the CRM areas of planning, communication, and crew interpersonal issues. Also, aspects of ORM relate to these accidents in the areas of mission environment, crew compliment, and pilot proficiency/experience.

These accidents are examples of CFIT, defined as an in-flight collision with terrain, water, trees, or man-made obstacle during forward flight (AFSA, 2003, p. 13). While the aviation community has learned much from previous CFIT accidents (Khatwa & Helmreich, 1999), these mishaps illustrate the sources of human error and aviation organizational failures in current operations. Table 1 depicts the high cost of USAF CFIT, midair collisions, loss of control, and taxi, take-off, and landing mishaps between 1993 and 2002, in terms of USAF aircraft, personnel, and money.

According to an Air Force Safety Center analysis, 1993-2002, "controlled flight into terrain takes [the] greatest toll: average 6 destroyed aircraft per year and average 13 fatalities per year" (AFSA, 2003, p. 22). CFIT accounts for approximately 22% of all Class A mishaps (AFSA, 2003, p. 11). Other totals of USAF mishaps are in-flight loss of control (LoC) at 12%, midair collisions at 9%, and taxi/take-off/landing at 8% of the total mishaps (AFSA, 2003, p. 11). These mishaps, when combined with CFIT, account for 51% of all Class A accidents. Note that these categories do not represent underlying causal factors per se, but instead indicate crew activities at the time of the mishap. Just as in civilian aviation, most USAF accidents were attributed to human error. Unfortunately, previous USAF safety analysis methods have not been sufficient to identify the underlying causes of the mishaps. In fact, one recent analysis "doubts the Air Force flight-mishap rate can be cut in half because there aren't widespread common problems" (Rolfsen, 2005b, p. 16). We believe however, that proper analysis can reveal these common problems. Furthermore, it is likely these commonalities represent latent failures that go beyond active errors made by pilots.

Department of Defense Human Factors Analysis and Classification System

DoD HFACS is based on Reason's (1990) theory of human error and the premise that "simply knowing how past disasters happened does not, of itself, prevent future ones" (p. 17). Reason (1990) emphasized the use of case studies married with theory to reduce or eliminate error consequences. The DoD HFACS (2005), shown in Figure 1, is based on the work of Wiegmann and Shappell's (1997) Failure Analysis Classification System (FACS), which has evolved over the years (1999, 2000, 2001, 2003). Wiegmann and Shappell's original FACS and the DoD HFACS are similar in theory and basic framework however the DoD HFACS is more detailed in its classification categories. Prior to adopting DoD HFACS, the USAF investigative process focused primarily on active errors made by the pilots and lacked the overall structure that DoD HFACS provides. Active errors are actions or inactions that directly lead to a mishap whereas latent errors are pre-existing conditions that may set-up a pilot to fail through a series of events. The previous USAF safety investigative system was useful and led to many safety improvements, however, DoD HFACS is an improvement because it "bridges the gap between theory and practice" (Shappell & Wiegmann, 2000, p. 13). Shappell and Wiegmann (2000) explain their model and its effectiveness:

> Therefore, it makes sense that, if the accident rate is going to be reduced beyond current levels, investigators and analysts alike must examine the accident sequence in its entirety and expand it beyond the cockpit. Ultimately, casual factors at all levels within the organization must be addressed if any accident investigation and prevention system is going to succeed (p. 2).

DoD HFACS captures the essence of the "domino theory" described by Brown (1995) that depicts accidents as part of a chain-of-events schema and stresses the combination of people and objects within an environment, as well as the temporal nature of their interaction. The domino theory has been modernized and incorporated in DoD HFACS as a "Swiss Cheese" model of human error in Figure 2 (DoD HFACS, 2005, p. 3). The DoD HFACS model identifies specific deficiencies (latent failures) that lead to the holes, when combined with certain events, align to produce incidents/accidents. The primary goal of this research is to use DoD HFACS as a framework to identify common latent errors for the purpose of mishap prevention.

Methods

This study examined a sample of 124 official USAF Safety Class A mishaps occurring between October 1992 and March 2005. Data reviewed included accident reports as well as summaries and findings of causes prepared by the USAF Safety Investigation Board (SIB). These reports were retrieved from the USAF Safety Center's secure accident database and re-analyzed to identify causal findings using DoD HFACS. Only those 124 Class A mishaps that fell into the categories of CFIT, spatial disorientation (SD), LoC, or midair collisions were sampled. One mishap extensively documented by Kern (1998), was not found in the USAF data locations but is included in the study. This was the April 1996, well-publicized CT-43 crash in Dubrovnik, Croatia, in which 6 USAF crewmembers and 29 passengers were killed. Kern's investigation was used to code this CFIT mishap into DoD HFACS.

These accidents were not re-investigated, only re-coded based on a summary of the accident and a list of findings and causal factors. This summary provided the SIB's perspective of the most important findings/causes and a macro-assessment of each mishap. In addition to the computer database of the accident summaries, a review of the actual SIB reports kept at the USAF Safety Center, Kirtland Air Force Base was also completed. It is emphasized that the previous USAF accident classification system, though lacking in the structure provided by DoD HFACS, did provide many of the same human factors terminology and concepts. Consequently, the re-coding was a straightforward process with little deliberation because DoD HFACS contains very specific descriptions and definitions of each category.

The first author accomplished the re-coding into DoD HFACS and served as the subject matter expert. His experience as a 20-year USAF pilot in five different aircraft, having flown over 3,300 flying hours, and a Masters degree in human factors allowed for reliable classification. The process consisted of examining all 147 different DoD HFACS categories for each mishap. Based on the actual USAF accident report, the information was re-coded with a 0 (no) or 1 (yes) as the binary process of converting previous mishap information into DoD HFACS. For example, a mishap that found failure in the supervisory chain of command to monitor crew experience of a young pilot for a challenging mission was classified into DoD HFACS as Supervisory Influence, Planned Inappropriate Operations, Limited Total Experience. Another example refers back to the 2002 mishap of the MC-130 in Puerto Rico, when the crew failed to respond to terrain warnings. The re-coding of that one factor of the mishap into DoD HFACS was Acts, Errors, Judgment and Decision-Making Error, Caution/Warning – Ignored.

Mishap Types

For the purpose of this study, CFIT is broken into two different categories. We define CFIT-1 as an airworthy aircraft unintentionally colliding with terrain, water, trees or a man-made obstacle during controlled flight. The USAF definition of CFIT is comparable to our classification of CFIT-1. We define CFIT-2 as an airworthy aircraft unintentionally colliding with terrain, water, trees or a man-made obstacle during controlled flight in the *approach and landing phase of flight.* This distinction was made to cover the USAF category of approach and landing accidents with a similar definition that is used in the commercial accident framework (Khatwa & Helmreich, 1998). Other mishaps types recorded were LoC due to stall, spin, or any other out-of-control condition, SD which also includes g-induced loss of consciousness, and midair collisions.

Results

This analysis was aimed at finding a common human factors trend between the mishaps and within each mishap. The classification of the active and latent errors of the accidents produced frequencies which were analyzed by aircraft type and mishap type. The information presented is the percentage of occurrence for the mishap type. Of the 124 mishaps, 109 (88%) were training missions and the remainder were operational or combat losses. The 109 training missions resulted in 173 fatalities. Table 2 summarizes the aircraft by mishap type. CFIT accidents (CFIT-1 & CFIT-2) occurred most often with 48 of the total 124 mishaps attributed to controlled flight into the terrain. Midair collisions accounted for 42 mishaps out of 124 total followed by CFIT-1 with 31, SD 19, CFIT-2 17, and LoC with 15. Fighter, attack, and reconnaissance (FAR) aircraft had by far the highest frequency of midair collisions and SD. Crew aircraft had 16 Class A mishaps with 14 of them CFIT 1/2, 8 of those were CFIT-1. Trainer aircraft exhibited a pattern similar to FAR aircraft with midair collision and LoC occurring more frequently.

DoD HFACS.

DoD HFACS allows for analysis of not just unsafe Acts, but also the latent failures that lead to these acts. The following sections will provide the frequency data for factors related to unsafe Acts, Preconditions to Unsafe Acts, as well as the associated Supervisory and organizational Influences.

Acts. DoD HFACS defines Acts as active failures or actions committed by the operator that result in human error or an unsafe situation (DoD HFACS, 2005, p. 6). As depicted in Table 3, unsafe Acts fall into four different sub-categories: (a) Skill-Based errors, (b) Judgment/ Decision-Making errors, (c) Perceptual errors, or (d) Violations. Across accident categories, Skill-Based errors and Judgment/Decision-Making errors were the most common type of Acts. Perceptual errors and Violations were cited much less frequently. Note CFIT-1 and CFIT-2 follow a similar pattern except that more Violations were associated with CFIT-2. Judgment/ Decision-Making and its subcategory of Risk and Decision-Making were the factors most often associated with both CFIT-1 and CFIT-2. LoC and midair collisions both share Skill-Based error as their leading causal factor, though LoC is dominated by Procedural errors within Skill-Based errors, whereas midair collisions are led by Breakdown of Visual Scan. SD is led by both Perception issues and Judgment/Decision-Making factors. Note within Judgment/Decision-Making, Task Misprioritization is a leading factor for SD mishaps.

Preconditions to Unsafe Acts. Table 4 shows the Preconditions to Unsafe Acts, defined as conditions of operators, environment, or personnel factors affect practices, conditions, or actions and result in human error or an unsafe situation (DoD HFACS, 2005, p. 7). The three main sub-categories of Preconditions to Unsafe Acts are Environmental factors, Conditions of Individuals, and Personnel factors. Of the nine total categories only the four most frequently cited are reported. Three of these factors are related to the Condition of the Individual: (a) Cognitive, (b) Psycho-Behavioral factors, and (c) Perceptual. The fourth falls under the Personnel area, Coordination, Communication, Planning (CCP) factor.

CFIT-1 and CFIT-2 had similar patterns with CCP factors most prevalent, followed by Cognitive factors, Perceptual, and then Psycho-Behavioral. The sub-factors within CCP for CFIT-1 were Mission Planning, Mission Briefing, Mission Re-Planning, and Leadership. In contrast, CFIT-2 was most frequently associated with the CCP sub-factors of Monitoring the other pilot, Mission Planning, Mission Re-Planning, Assertiveness, and Leadership. Interestingly, LoC was led by the Psycho-Behavioral factor, which is defined as an individual's personality traits, psychosocial problems, psychological disorders, or inappropriate motivation creating an unsafe situation (DoD HFACS, 2005, p. 8). Within the Psycho-Behavioral category for LoC were sub-factors of Over-confidence, Complacency, and Over-aggressiveness.

Cognitive factors were frequently associated with all accidents types. They were the most common factors associated with midair collisions and second for all other mishap types. Within Cognitive factors the most frequent sub-factor was Channelized Attention. Channelized Attention is defined as an individual 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 (DoD HFACS, p. 1-7).

Not shown in Table 4 but of interest is the presence of instrument meteorological conditions (IMC) which is a Physical Environment Precondition to an Unsafe Act. IMC is categorized by DoD HFACS when vision is restricted due to weather, haze, or darkness (2005, p. 1-5). This category accounted for 71% of CFIT-2, 63% of SD, and 42% of CFIT-1 mishaps. When combining CFIT-1 and CFIT-2, 52% of CFIT mishaps occurred in vision restricted environments.

Supervisory and Organizational Influences. Supervisory Influences are defined as methods, decision, or policies of the supervisory chain-of-command directly affecting practices, conditions, and actions resulting in human error or an unsafe situation (DoD HFACS, 2005, p. 1-18). This category of DoD HFACS directly contributes to Preconditions of Unsafe Acts discussed in the previous section, and is thus critical to aviation safety. Unfortunately, the previous USAF Safety investigation system did not consistently document findings in this area. Therefore, analysis of Supervisor as well as Organizational Influences, was difficult and somewhat limited.

Supervisory Influences fall into four sub-categories: (a) Inadequate Supervision, (b) Planned Inappropriate Operations, (c) Failures to Correct Known Problem, and (d) Supervisory Violations. Table 5 depicts the frequency of these occurrences. Planned Inappropriate Operations were the most prevalent sub-category across all mishap types. These instances of Planned Inappropriate Operations were primarily due to Inadequate Proficiency, Experience Level (total and recent), and Risk Assessment. This finding is somewhat troublesome given the USAF emphasis on ORM at all levels of operations. Furthermore, ORM specifically targets mission risk (sortie difficulty and weather) with crew capabilities in terms of Experience and Proficiency.

Organizational Influences are not specifically discussed due to the difficulties encountered in re-classification of the previous USAF system into DoD HFACS at the Organizational Resource, Process, and Climate levels. Although, there were thorough discussions regarding Organizational Influences for some mishaps in the previous USAF system, their scope was limited to allow credible classification into the DoD HFACS framework. In general, the limited analysis indicated potential deficiencies in categories of Publications and Training as well as Resource Acquisition of fleet-wide modifications and training devices. Common examples of these were recommendations calling for improved SD training devices and improved training publication directives.

Discussion

Reason (1990) described latent errors as, "the significance of causal factors present in the system before an accident sequence actually begins" (p. 197). Re-classification of previous USAF accidents within the DoD HFACS framework provides the data to target root causes and improve mishap prevention programs. In order to make best use of available resources prevention measures should focus on the areas with the greatest return, the holes in the cheese that are most manageable and those where the precursors are more susceptible to an antidote. DoD HFACS (2005) describes the trends of contributing factors in accidents, "if you know what these system failures/hazards or 'holes' are, you can better identify their roles in mishaps – or better yet, detect their presence and develop risk mitigation strategy correcting them *before* a mishap occurs" (p. 4). This study provides the data to initially identify and potentially mitigate common latent hazards contributing to USAF accidents.

The focus of this research is to highlight latent errors in order to facilitate further mishap reduction. While studies of active errors have great value (Fitts & Jones, 1961; Khatwa &

Helmreich, 1999; Kowalsky et al., 1974; National Transportation Safety Board, 1994; Zeller, 1981), errors are best prevented by addressing the organizational, supervisory, and other preconditions that lead to these unsafe acts. While technology can reduce error, it often merely changes the nature of errors and allows for expression of new active error types. Reason (1990) and the research model of Shappell and Wiegmann (2000) stress elimination of the organizational latent hazards to mitigate risk, that is elimination of the holes in the cheese further up the chain-of-events. This re-analysis of USAF mishap data has allowed us to identify the latent factors that contribute to observed mishap types. This analysis provides a framework for mitigation measures targeted at these latent error types. The following section proposes mitigation strategies aimed at the observed latent errors associated with CFIT, midair collisions, and spatial disorientation mishaps. It is emphasized that the original research intentions were not focused on CRM and ORM constructs and it was surprising that mishap trends fell into those areas.

CFIT-1 & CFIT-2

Our analysis suggests that CFIT accidents are most often associated with the unsafe Acts category of Judgment/Decision making. The main Preconditions to these Unsafe Acts are Coordination, Communication, and Planning (CCP) factors, all of which are USAF CRM topic areas. This prevalence is somewhat surprising since CRM training has been emphasized in all aviation communities over the last 20 years. The USAF guidance on CRM describes the six dimensions of CRM as situational awareness, crew coordination/flight integrity, communication, risk management/decision making, task management, and mission planning/debriefing (AFI 11-290, 2001, p. 5). Yet, those areas frequently contributed to the mishap types analyzed in this study, particularly recent CFIT mishaps.

Our findings parallel with Nullmeyer, et al.'s (2005) work examining CRM in fighter (F-16 and A-10) and transport (C-130) aircraft. In their assessment of 21 F-16 mishaps and 19 A-10 mishaps they found situational awareness, task management, and risk management/decision-making CRM dimensions most frequent. The 8 C-130 mishaps had an even distribution of all six CRM dimensions. They concluded that CRM-related human factors are areas to focus mishap prevention measures.

Cognitive factors associated with CFIT can be addressed by drawing on CFIT reduction training developed in civilian aviation. A thorough assessment of worldwide aviation accidents was reported by the Flight Safety Foundation (FSF) in their Flight Safety Digest and featured research by Khatwa and Helmreich (1998). These authors accomplished analysis of 287 fatal approach and landing accidents (ALA), similar to our CFIT-2 category, between 1980 – 1996, and detailed case studies of 76 ALAs and serious incidents from 1984 – 1997. The FSF's report concluded with ambitious and necessary recommendations for aircraft equipment, instrument approach plates and approach procedures for continuous descent stabilized approach criteria, as well as a mass pilot education program (pp. 50 – 51). The training program was delivered throughout the aviation industry with the goal of reducing ALA/CFIT by 50% in five years (FSF News, 1998, p. 5).

Technology provides assistance with attention, task management, and perceptual factors by identifying unsafe conditions, depicting terrain and obstacles and alerting pilots to unsafe conditions. Following the CT-43 crash in Croatia, the USAF embarked on a program to equip all passenger and troop carrying aircraft with Ground Proximity Warning Systems (USAF/XO memo, 9 Sep, 1996). Most of these aircraft are/will be equipped with the newer generation Terrain Awareness and Warning Systems (TAWS) which provide a visual depiction of terrain and a "look ahead" capability. As in the case of collision avoidance equipment, the challenge is to provide non-transport aircraft with a similar capability.

Head-Up Displays (HUDs) also mitigate attentional and perceptual issues associated with CFIT since they can bring attentional focus off the instrument panel and allow focus on the external environment. The HUD can also project a visual approach-landing glide-path, which can be of great help when flying a non-precision approach or a visual approach in less-than-optimal visual conditions. Khatwa and Helmreich (1998) found that 75% of CFIT accidents occurred when flying a visual or non-precision approach. HUDs are common in FAR aircraft and they are also beginning to be installed in some commercial transport aircraft as well.

Procedural mitigation strategies can also be applied. For example, most commercial airlines have established standards, stabilized approach criteria that address required airspeed, glide-path, altitude, and vertical-velocity "windows" to continue an approach or accomplish a missed-approach called (Khatwa & Helmreich, 1999). These criteria are different depending upon visual or instrument conditions. The USAF has performance skill requirements for evaluation purposes however the USAF does not currently have formal guidance on implementation of stabilized approach criteria and procedures for use as decision-making aids.

Another aircrew operational policy change to reduce mishap risk is adopting procedures that require the co-pilot/first officer (the less senior pilot) fly during challenging portions of the mission. This would allow the senior pilot to accomplish risk assessment and handle tactical decision-making issues that are commonly cited as causal in mishaps. Judgment and decision-making errors were more prevalent in CFIT-1, CFIT-2, and SD mishaps compared with skill-based errors. According to an NTSB report (1994) of flight-crew involved major accidents from 1978 – 1990, the captain/senior pilot was flying in 30 of 37 accidents, 81% (p. 38). The NTSB

(1994) report and Berman (1995) both concluded that a senior pilot would be a more proactive communicator to monitor and challenge a junior pilot during an approach and landing. Swauger (2003) suggested pilots fail to recognize their poor decisions and incorrectly apply common decisions to unique situations in turn providing more evidence of a senior non-flying pilot better able to make prudent decisions.

Midair Collisions

Skill based errors, specifically Breakdown in Visual Scanning procedures, are the unsafe Act most commonly associated with midair collisions. Another major type of unsafe Act is the Judgment/Decision Making factor of Task Misprioritization. The associated Preconditions are the Cognitive factors of Channelized Attention, Inattention, and Task Over-Saturation. Also, another Precondition to Unsafe Act is the role of CCP categories of Mis-Communication, Leadership, and Planning.

The primary Supervisory Influences are Inappropriate Planned Operations as expressed by the sub-factors of a Lack of Proficiency and Experience. Given that USAF will continue to use relatively young and inexperienced pilots training should focus on Task Management. An additional area of interest is the presence of Inadequate Supervision in the sub-factors of Training and Policies. Development of improved procedures and training may be an effective means of mitigating areas such as a lack of experience and proficiency.

Technology can also overcome some of these factors. Studies have shown that the human ability to detect and avoid potential collisions may be poor, especially in complex and fast paced fighter operations (Morris, 2005). While most USAF transport and trainer aircraft are equipped with TCAS to counter these known deficiencies, fighter aircraft do not have a similar system.

Spatial Disorientation

Perception and Judgment errors were the unsafe Acts most frequently identified in SD mishaps. The preconditions for these acts included Cognitive and Perceptual factors related to attention and misperception. Once again, limited Proficiency and lack of Experience were the most common Supervisory factors related to these preconditions. In other words, lack of proficiency and relative experience put USAF pilots at risk for attentional and perceptual problems that lead to judgment errors and misperceptions.

Providing training to help aircrew identify and mitigate SD risk factors continues to be an important USAF program. Much of this training is provided by USAF Aerospace Physiologists on a recurrent basis. For many years the USAF aerospace physiology training was required once every three years. This training consisted of an academic portion with a review of pilot "airworthiness" issues ranging from human performance, vision, mental/physical fatigue, visual/vestibular misperceptions and night flying (AFI 11-403, 2001). This training was then followed by a "flight" in an altitude chamber to review symptoms of hypoxia and an actual rapid-decompression scenario. This training requirement was extended to once every five years (AFI 11-403, 2001).

Beyond SD-specific accidents, SD is also a contributing factor to CFIT-1, CFIT-2 and LoC mishaps. Numerous safety boards recommended improved SD training devices. Aerospace physiology is training conducted by human factors specialists equipped to address topics commonly listed as Preconditions to Unsafe Acts. Hypoxia is a rare event and the rationale to extend training for it as an environmental hazard is logical, however, the associated academic SD training that accompanies it is vital education for pilots and should be provided on a more regular basis. In addition to training, continued efforts must be made in attentional cueing and other measures to counter SD.

Mathews, Previc, and Bunting (2002) presented results from a USAF SD survey they administered to 2,582 pilots. Their survey found the most frequent visual illusions were sloping horizon, atmospheric blending, and black hole (featureless terrain) approaches whereas the most frequent non-visual SD were the leans, Coriolis illusion, and G-excess illusion. Mathews et al. concluded that different types of aircraft had different types of SD and training programs must address the unique aviation operations. Gillingham (1992) had also advocated improved training for SD due to increased night operations and the role SD plays in aviation mishaps. This assessment is similar to CRM recommendations regarding more specifically tailored training per aircraft type (Nulmeyer, et al., 2005; Wiegmann & Shappell, 1999).

Operational Risk Management

The role of supervisors in mishap prevention is an area of great concern. This study indicated that supervisors contributed to USAF mishaps by failing to adequately mitigate limitations on aircrew proficiency and experience. Additionally, inadequate supervision, training, and policies contributed to all accident categories. Due to limitations in the existing data we were not able to draw strong conclusions regarding common trends in supervisory and organizational factors. It is vitally important that future safety investigations are trained for, and actively assess supervisory and organizational factors. Continuing and improving upon ORM assessments at all levels of the organization is a critical preemptive measure to counter these latent errors because ORM allows flying unit leadership to continuously assess their organization on a daily basis for safe and prudent operations.

Data Collection Before the Accident Occurs

The focus of this research is on latent errors. DoD HFACS was used to assess mishaps and an attempt was made to draw inferences for system improvements from classification of accident events. This process is reactive. A medical analogy has been used to describe mishap analysis as similar to performing an autopsy, accident classification is post-mortem in that anything learned is too late for that particular patient (International Civil Aviation Organization [ICAO], 2002). Also improvements made after an accident fix the "last accident" but fail to address other system failures. Describing mishaps is pointless unless proactive measures are taken to improve the aviation system. Incident analysis is more effective than mishap analysis because it highlights system limitations/weaknesses prior to a mishap occurring (ICAO, 2002). Two growing programs in aviation that are *pro*active are Flight Operational Quality Assurance (FOQA) and Line Operational Safety Audits (LOSA). These two safety initiatives collect data during normal operations prior to incidents and accidents and allow for the measurement and analysis. The data translates into information of potential hazards and risks resulting in proactive mitigation measures.

FOQA programs obtain and analyze data recorded during flight operations to help determine how the aircraft is being operated in terms of the pilot's actions, the aircraft's responses, and the environment the aircraft operates within (FSF, 2004). In terms of the medical analogy, FOQA is a continuous diagnostic assessment of a healthy system. FOQA tracks pilot performance for procedure compliance as well as environment operating situations to aid in training. FOQA records aircraft system component performance and communications with Air Traffic Controllers (ATC). FOQA has been used to identify unstabilized approaches, flap overspeeds, excessive banking, engine over-temperatures, TAWS alerts, and glide path deviations (FSF, 2004).

FOQA is not intended to "blame" pilots, the data is analyzed and assessed for the purpose of trend identification and proactive safety improvement. Examples of proactive measures taken to improve operations based on FOQA data had one airline determining that more procedural non-compliance was occurring during visual approaches compared to instrument approaches and hence training was re-focused (US General Accounting Office [US GAO], 1998). Another example was found by an airline that at a certain airport the required descent-rate was being exceeded and upon further investigation it was found that ATC was to blame due to their handling of in-bound aircraft (US GAO, 2004).

LOSA, is similar to an annual flight physical, periodically using expert observers to collect data on flight crew performance as the pilots interact with the aircraft, the operational environment, and each other (Federal Aviation Administration [FAA], 2006). LOSA is not a check-ride, only an observation of how operations are being conducted in terms of CRM concepts analyzed with a tool based on Threat and Error Management (ICAO, 2002). CRM is in place to deal with recognized error occurrences (FSF, 2005) and LOSA is a process to capture how successful operations are accomplished rather than the negative/reactive approach of accident investigation. LOSA can help an airline by identifying threats to the operating environment, operating procedures, assessing transfer of training to operations, human/machine interface, safety margins, and pilot work-arounds (FAA, 2006, pp. 3-4).

Conclusion

Implementation of the DoD HFACS analysis framework provides a clear understanding of the root causes at various levels from unsafe acts through organizational influences. It can also be used to propose associated mitigation strategies. This research re-analyzed existing USAF mishap data using the DoD HFACS framework and proposed focused solutions to common causal latent factors. The FY 2005 mishap rate of 1.44 (Rolfsen, 2005b) is higher than the last 10-year average of 1.32. Aviation safety concerns are not limited to only the USAF. Recently the US Navy ordered a mandatory "navy-wide safety stand-down" in response to 6 crashes resulting in 7 fatalities within the first two months 2006 (McMichael, 2006, p. 32).

Dekker (2003) discounts error classification and rightfully so if it stops at only describing past failures and blaming aviators involved. This research, accomplished by Air Force pilots, attempts to link descriptive safety reports to existing organizational latent factors. Dekker (2005) investigated in detail the Alaskan Airlines Flight 261 accident in 2000. He used this mishap to example an organization's drift into failure. Our assessment of 124 mishaps is a macro-example of how current initiatives, in-place to improve aviation operations (CRM/ORM), are not stopping a possible drift toward failure. This research never expected to expose CRM and ORM failures however illuminating their limitations may prove to encourage implementation of needed proactive FOQA and LOSA safety programs for the collection of data during normal operations prior to incidents and accidents.

Reason stated, "disasters are very rarely the product of a single monumental blunder," thus no single act can expect to improve aviation safety (1990, p. 17). Therefore, a systemic approach to aviation safety is needed at all levels, organizational and supervisory, as well as individual pilot(s) to reduce the mishap rate. No accident is acceptable and improvements in safety programs and updating aircraft with currently available technology can greatly reduce the risk of a mishap and eliminate the holes in the cheese.

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DISCLAIMER

The opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the USAF and/or the Department of Defense.

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Table 1

USAF 10-year totals of CFIT, Midair, Loss of Control, and Taxi, Take-off, & Landing mishaps 1993 – 2002

	Destroyed Aircraft	Fatalities	Dollars (FY01 $)
CFIT	59	132	$1.94 Billion
Midair Collision	37	90	$776 Million
Loss of Control	31	22	$776 Million
Taxi, Take-off, & Landing	12	5	$205 Million
Total	139	249	$3.7 Billion

Note. CFIT – Controlled Flight into Terrain defined by the Air Force as in-flight collision with terrain, water, trees, or man-made obstacle during forward flight. FY01 $ – fiscal year 2001 dollars, fiscal year 1 Oct to 30 Sep. Adapted from Air Force Safety, 2003, p. 13, p. 15, & p. 17.

Table 2
Total of each mishap type by aircraft category

Aircraft Type	CFIT-1	CFIT-2	LoC	SD	Midair	Total
FAR	17	6	9	19	34	85
Crew	8	6	0	0	2	16
Helicopter	6	3	1	0	2	12
Trainer	0	2	5	0	4	11
Grand Total	31	17	15	19	42	124

Note. FAR – fighter, attack, reconnaissance.

Table 3
Percentage of DoD HFACS category classification of Unsafe Acts by mishap type

HFACS Error	**CFIT-1**	**CFIT-2**	**LoC**	**SD**	**Midair**
Total Classifications	84	55	31	44	94
Skill-based	27% Proc 39% Scan 39%	25% Proc 50% Ov/Un C 29%	**52%** **Proc 44%** **Ov/Un C 38%**	23% G-strain 50% Scan 20%	**47%** **Scan 82%** **Proc 18%**
Judgment/DM	**54%** **Risk 38%** **DM 31%** **TskMP 22%**	**44%** **Risk 46%** **DM 33%**	19% DM 50% Risk 23%	**36%** **TskMP 56%** **Risk 19%**	30% Tsk MP 56% DM 21%
Perception	13%	16%	10%	**36%**	18%
Violation	6%	15%	19%	5%	5%

Proc = procedure; Scan = breakdown of visual scan; Ov/Un C = over/under control; G-strain = improper G=straining technique; Risk = risk assessment; DM = decision-making; TskMP = task misprioritization;

Table 4

Percentage of DoD HFACS category classification of Preconditions to Unsafe Acts by mishap type (only the 5 leading causes displayed out of the 9 possible categories).

HFACS Preconditions	**CFIT-1**	**CFIT-2**	**LoC**	**SD**	**Midair**
Total Classifications	171	119	43	96	118
Cognitive factors	22% ChanAtt 48% Distrct 21% Inatt 18% TskOvst 18%	19% ChanAtt 48% TskOvst 17% Distrct 17%	16% ChanAtt 57%	23% ChanAtt 55% TskOst 23% Distrct 18%	**43%** **ChanAtt 47%** **Inatt 22%** **TskOst 16%**
Psycho-Behav	17% Compl 24% Oconf 21% RspSt 21% ExSucc 18%	18% ExSucc 24% Compl 19% Press 15%	**35%** **Oconf 27%** **Compl 27%** **Oaggres 27%**	---	14% RspSt 50% Compl 18%
Perceptual	18% MispCnd 61% SDO 19%	18% MispCnd 62% VisIll 24% SDO 14%	14% MispCnd 50% SDO 50%	**31%** **SD 50%** **MispCnd 27%**	---
CCP	**27%** **MsnPln 24%** **Brf 15%** **Repln 13%** **Ldrshp 13%**	**28%** **Monitr 21%** **Plan 18%** **Repln 12%** **Assert 12%** **Ldrshp 12%**	16% Ldrshp 29% Monitr 29%	---	19% Miscom 30% Ldrshp 26% Plan 13%

Env = Environmental; Behav = Behavioral; Physio = Physiological; CCP = coordination/communication/planning factors; Chan Att = channelized attention; Distrct = distraction; Inatt = inattention; TskOvst = task oversaturation; Compl = complacency; Oconf = over confidence; RspSt = response set; ExSucc = excessive motivation to succeed; Press = pressing; Oaggres = over aggressive; MispCnd = misperceived conditions; MsnPln = mission planning; Brf = briefing; Repln = Re-plan mission during mission; Ldrshp = leadership; Assert = assertiveness; Monitr = monitor other pilot; Miscom = miscommunication

Table 5
Percentage of DoD HFACS category classification of Supervisory Influences by mishap type

HFACS Error Total Classifications	**CFIT-1** 39	**CFIT-2** 23	**LoC** 23	**SD** 19	**Midair** 22
Inappropriate Operations	**82%** **Risk 31%** **Profic 25%** **Exp 19%**	**65%** **Profic 40%** **Exp 40%**	**61%** **Profic 50%** **Risk 21%** **Exp 21%**	**74%** **Exp 43%** **Prof 36%**	**37%** **Prof 35%** **Exp 35%**
Inadequate Supervision	15% InadSup 83% LclTrn 17%	26% InadSup 66% LclTrn 17% Feedbck 17%	35% InadSup 50% LclTrn 25%	21% LclTrn 50% Policy 25% Model 25%	23% LclTrn 40% Policy 40%

Profic = Proficiency; Exp = total and recent experience; Risk = risk assessment; LclTrn = local training; model =

Figure 1. DoD HFACS (Air Force Safety Center, 2005).

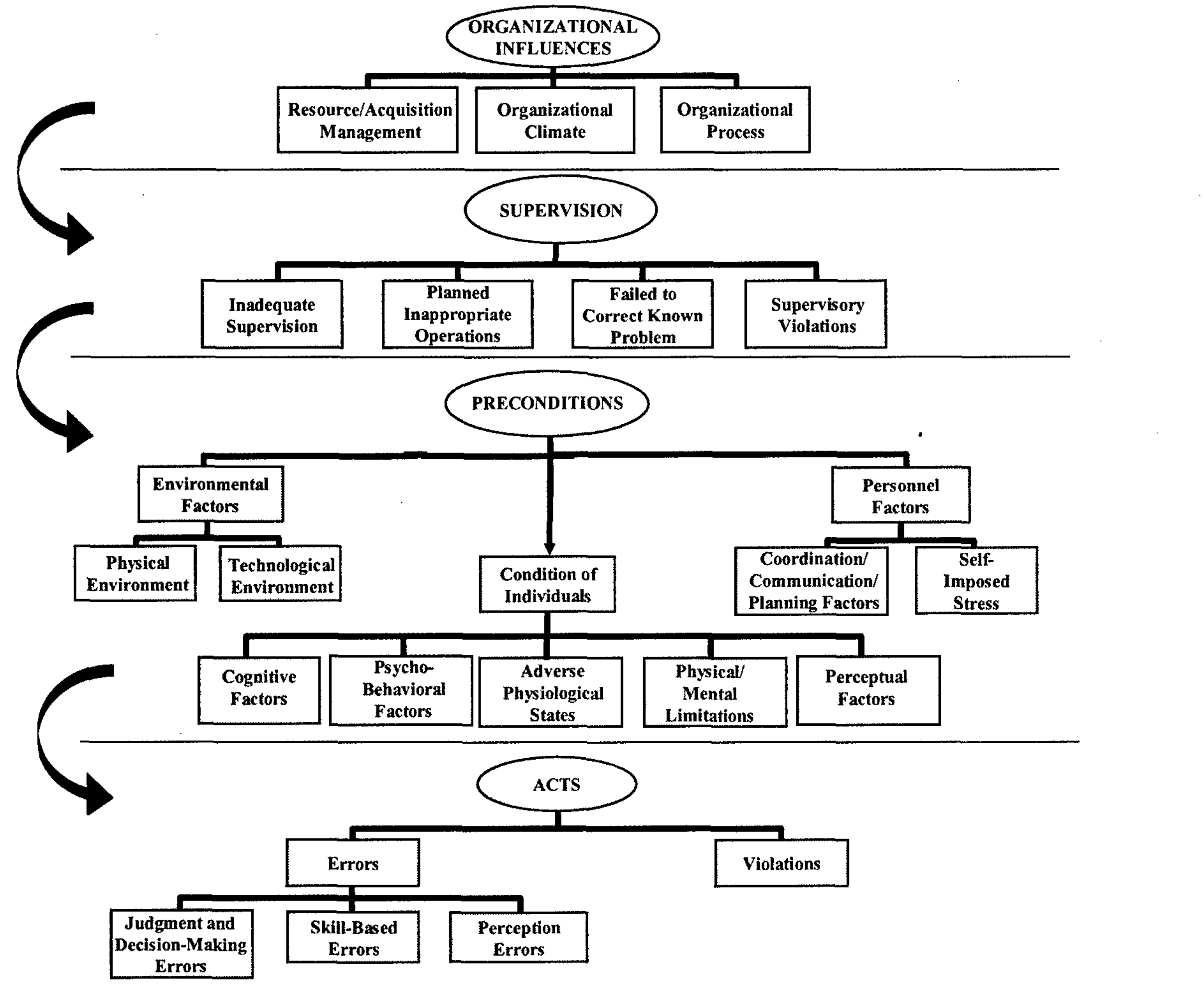
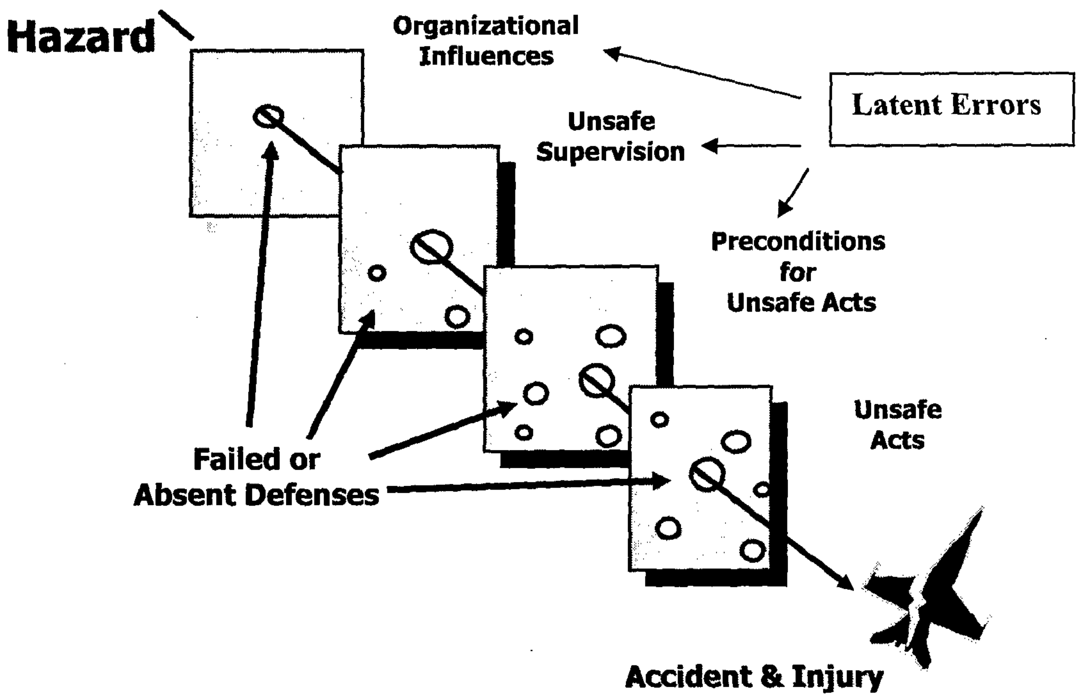


Figure 2. Swiss-cheese model (Air Force Safety Center, 2005).



BIOGRAPHY

Randall Gibb is a Lieutenant Colonel in the United States Air Force and graduate student at Arizona State University, Tempe, AZ. In 1996, he received his M.S. E. in Industrial Engineering, Human Factors, from Arizona State University. He has over 3,300 flying hours in the United States Air Force in the T-38, C-5, T-3, C-21, and T-1 aircraft.

Wes Olsen, is a really good dude that is helping me with this paper☺, he has triplets (3 boys), so how he has time to help me is amazing…