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Mishap Trends in Several Air Force Aircraft: Implications for CRM Training

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Human factors trends in C-130, F-16, and A-10 mishaps were reviewed for relevance to cockpit/crew resource management (CRM) course content. The current Air Force Safety Center human factors taxonomy includes about 360 detailed human factors elements. About sixty of these taxonomy elements map directly into the six CRM core areas identified in Air Force Flying Operations publications (communication, risk management/decision making, situational awareness, task management, crew coordination/flight integrity, and mission preparation/ debriefing). This small fraction of human factors elements accounted for well over half of the causal and strongly contributing factors cited in each platform. The relative contributions of specific CRM core areas varied across applications. Tactical airlift mishap CRM factors were fairly uniformly distributed across all six traditional CRM areas. In F-16 and A-10 mishaps, task management and situational awareness were particularly frequent causal and major contributing factors. Planning, flight integrity, and communication were rarely cited. We describe the mishap data that are available from the Air Force Safety Center, our analytic approach, trends identified, and implications for CRM training. We anticipate that these analyses will contribute to better focused CRM training objectives and course content that will, in turn, enable CRM training to be a major contributor to the success of recent Department of Defense efforts to reduce preventable mishaps.

Introduction

Secretary Rumsfeld challenged the Services to reduce mishap and accident rates by at least 50% over a two year period. A Joint Service Safety Conference (JSSC) was established to develop a unified approach for meeting the Secretary's challenge. Many researchers have documented the large role played by human factors in flight mishaps. For example, Helmreich and Fouchee (1995) reported that flight crew actions were causal in more than 70% of worldwide accidents from 1959 to 1989 involving aircraft damage beyond economic repair. Similarly, Luna (2001) reported that human factors were major contributors or causal in over 60% of Air Force Class A mishaps from 1991 to 2000. Such long term trends suggest that meeting the Secretary's challenge will require solutions to human factors problems, and as a result, a Human Factors Working Group was established as a critical part of the JSSC. Analyses of recent aviation mishaps across the services by this working group revealed that Crew Resource Management (CRM) issues are still frequently cited in aviation mishap reports across the services.

Helmreich, Klinect and Wilhelm (1999) define CRM skills as "a primary line of defense against the threats to safety that abound in the aviation system and against human error and its consequences" and state that, to be effective, CRM training must be based on detailed knowledge of current safety issues. CRM training requirements for Air Force aviators reflect a similar safety focus in Air Force Instruction (AFI) 11-290, *Cockpit/Crew Resource Management Training Program* (2003). AFI 11-290 states that the objective of CRM training is to "develop aircrew skills in recognizing and responding to the conditions that lead to aircrew error." Six core curriculum areas are specified: situational awareness (SA), risk management/decision making, mission planning/ debrief, task management, crew communication, and coordination/flight integrity.

Helmreich, et al. (1999) identified five critical data sources: 1) formal evaluations of flight crews; 2) incident reports; 3) surveys of flightcrew perceptions regarding safety and human factors; 4) information on parameters of flight from flight data recorders; and 5) line operations safety audits (LOSA). Each illuminates a different aspect of flight operations. They proceeded to explore lessons learned from LOSA data.

Given the numbers of human factors-related Class A mishaps (loss of life, a destroyed air frame, or more that $1 mission damage), it only makes sense to learn as much as possible about the factors that most often led to these outcomes in the past. Mishap summaries are often used to develop case studies for CRM training and guide content of simulator refresher scenarios.

The full Class A mishap reports also include much more detailed descriptions of the human factors that caused or contributed to the undesired outcome. Unfortunately, analyses and application of these detailed human factors data have been rare in the training community. That picture is changing. CRM factors in C-130 Class A mishaps were recently analyzed (Nullmeyer, Stella, Flournoy, and White, 2003) as part of a larger program to improve CRM instruction for C-130 tactical airlift crews. Elements from all six core CRM areas were frequently cited in C-130 mishaps from 1990 through today. Within each CRM area, however, a small subset of elements accounted for the vast majority of causal or strongly contributing factors. This information was used to focus C-130 CRM training content on particularly problematic elements (Deen and Wilson, 2003).

Based on this initial success, analyses were recently expanded to include A-10 and F-16 Class A mishaps. Our focus in this paper is on major trends found in the more detailed C-130, F-16, and A-10 mishap reports, including commonalities and differences across platforms. We recognize that mishap reports are not sufficient by themselves to structure CRM training. Maurino (1999) correctly states that if we only look at accidents and incidents, we only learn about CRM failures. Dekker (2003) describes several potential problems with over-reliance on human error taxonomies, including risks associated with removing the context that helped produce the error.

These concerns suggest that detailed mishap human factors trends need to be viewed in the context of other information to develop truly robust CRM training. For example, instructor comments in student records were reviewed and CRM behaviors exhibited in annual simulator training were captured as part of the earlier review of C-130 CRM training (Spiker, Wilson and Deen 2003). Both enabled visibility into both positive and negative behaviors, and the simulator study in particular, allowed naturalistic observations of crew interactions and mission performance in the context of complex and demanding simulator scenarios.

Mishap Data Sources

The Air Force Safety Center documents Class A mishaps at varying levels of granularity. The analyses reported here combine data from all four data sources.

The Air Force Safety Center home page (http://afsafety.af.mil/) provides considerable summary mishap statistical information including hours flown and mishap frequencies by aircraft type, by year. Mishap frequency counts were used to check the completeness of other data sources. Flying hours per year were essential for determining mishap rates per 100,000 flying hours.

Mishap Summaries are executive summaries of the Safety Investigation Board's report (Tab T of the full report). They include information such as the mishap date, location, day or night, type of mishap (e.g, midair collision), phase of flight, and other descriptive data. It provides a one paragraph description of the mishap, and lists findings and recommendations.

A detailed **Human Factors Database** is populated and maintained by Air Force Safety Center Life Sciences analysts who use a common human factors taxonomy to structure findings regarding role played by operators, maintainers, and other personnel in each Class A mishap. The database includes dozens of fields. In the analyses reported here we focused on the human factors that were cited along with a rating for each factor ranging from "causal" (4) major contributor (3) and minor contributor (2), to minimal contributor (1) that indicates the degree to which each factor was involved in the outcome.

A **Life Sciences Report** is part of the full Class A mishap report (Tab Y). It provides fairly detailed discussions of **each** element cited in the human factors database and identifies interrelationships among the human factors. These discussions are extremely useful for understanding the actual behaviors underlying the human factors data base entries.

Time Frames of Anaylses. Mishap frequencies by aircraft type and year were used to determine the time periods to be included in subsequent analyses. As can be seen in Figure 1, there have been many more F-16 mishaps in the past few years than A-10 or C-130 mishaps. In an effort to achieve a reasonable sample size and maximize currency, we analyzed F-16 mishaps from 2000 through 2004, but expanded the time frame back to 1995 for C-130 and A-10 mishaps. These time frames resulted in 31 F-16 mishaps, 20 A-10 mishaps, and 8 C-130 mishaps.

Data Structure. The Life Sciences Branch, Aviation Safety Division of the Air Force Safety Center provided access to A-10, F-16, and C-130 databases to identify human factors that caused or contributed to Class A mishaps in these Air Force communities. The Air Force Safety Center's human factors taxonomy was first reviewed to identify elements that are relevant to CRM. About sixty of the 360 detailed taxonomy elements were determined to be CRM-related. These were then mapped into to the six CRM areas specified in Air Force Instruction (AFI) 11-290 as follows:

Perceptual and attention management elements were mapped into situational awareness (SA).

Task management factors included procedural elements and task misprioritization.

Risk management and decision making elements came primarily from the judgment and decision making node of the mishap taxonomy.

In-flight analysis and in-flight planning were added to preparation factors to create the mission planning and debriefing.

Communication was a preexisting node in the mishap taxonomy that encompassed both intra-cockpit interactions and interactions with external to the aircraft.

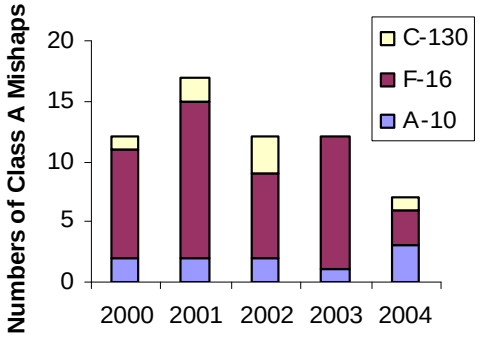
Elements of the cockpit/ crew resource management node (e.g., leadership, subordinate style and crew coordination) were combined with hazardous attitude elements based in the definition of crew coordination/flight integrity provided in AFI 11-290.

Results

The numbers of mishaps in which each CRM area was represented as least once as a causal or strongly contributing factor is depicted in Figure 2 as an annualized number. In the past decade (1995-2004) , there were over 100 F-16 Class a mishaps, 19 A-10 Class A mishaps, and 8 C-130 Class A mishaps. We included all of these A-10 and C-130 mishaps in this analysis. Due to the large numbers of F-16 mishaps, we focused on mishaps from the last five years. Twenty one of these mishaps were attributed to human factors. The remaining Class A mishaps were primarily loss of engine or bird strike, for which human factors were not cited.

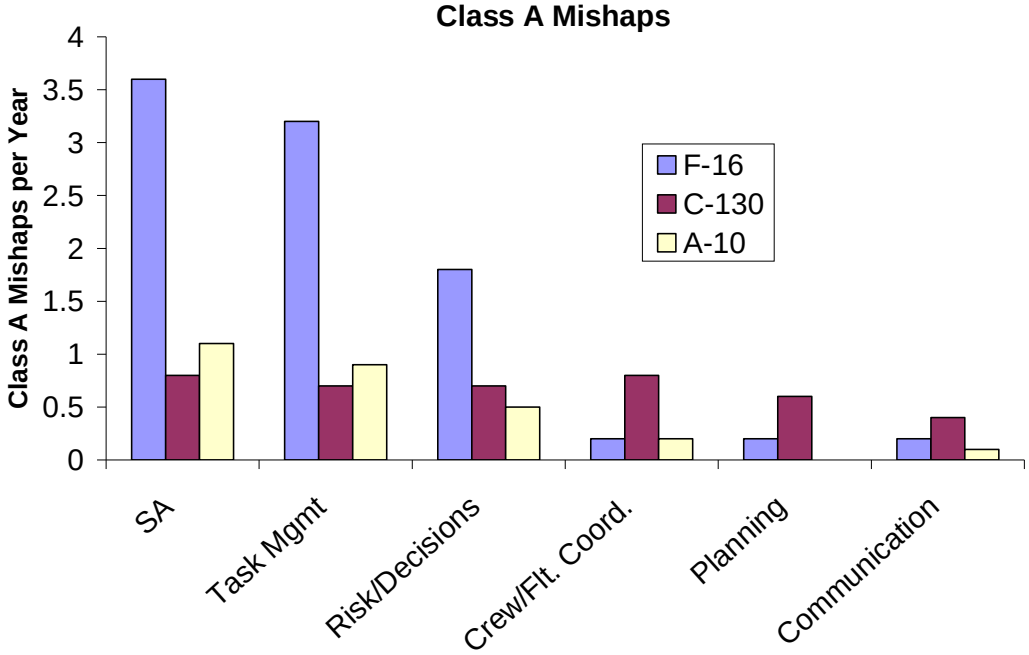
Mishap frequencies. The numbers of Class A mishaps over the past 5 years are shown in Figure 1 for C-130, A-10, and F-16 aircraft. There were notably few F-16 Class A mishaps in the most recent year (2004).

Figure 1: Class A Mishap Frequencies 2000-2004



CRM as a Causal or Major Contributing Factor. CRM-related factors and their numerical ratings were extracted from the human factors database for each mishap. Data from individual CRM-related factors were combined into the six CRM dimensions specified in AFI 11-290. From these consolidated data sets, we determined the number of mishaps in which a CRM dimension was cited at least once as a causal or major contributing factor. The resulting frequencies

Figure 2: CRM Core Areas as Causal or Major Factors in Class A Mishaps



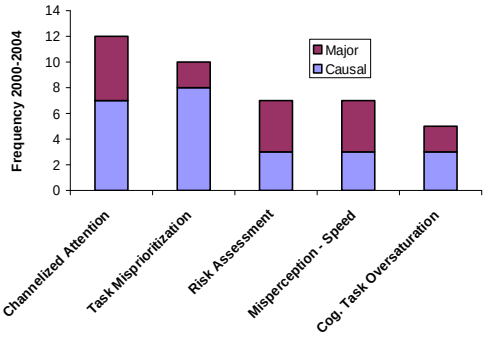
were converted into frequencies per year. The resulting rates are depicted in Figure 2. In C-130 Class A mishaps, causal and major contributing factor rates were fairly evenly distributed across the six CRM dimensions. For A-10 and F-16 mishaps, however, rates were much higher in some CRM areas than others. Rates were particularly uneven For F-16 mishaps. SA, task management, and risk management factors were cited frequently. Planning, flight integrity and communication were rarely cited.

Underlying CRM-Related Factors - We now shift the focus to the specific CRM–related human factors that were most frequently cited as being causal or strongly contributing in Class A mishaps. The top five factors are first listed for each platform. Commonalities and differences across platforms are then discussed.

F-16 CRM-Related Factors. The five specific human factors that were most frequently cited in F-16 Class A mishaps from 2000 through 2004 are shown in Figure 3. The first, fourth and fifth most frequent F-16 factors were directly related to SA. The remaining two were directly related to task management and risk assessment. In fact, all 10 leading human factors in F-16 mishaps were related to the SA, task management, or risk assessment/decision making areas of CRM

.Channelized Attention, cited most frequently, is a factor when the pilot is focusing conscious attention on a limited number of environmental cues to the exclusion of others of subjectively equal, higher or more immediate priority leading to an unsafe situation. Recent examples included attending to broken equipment inside the cockpit during low level flight, and relying exclusively on the Radar/Electro-Optical (REO) display while ignoring all other instruments, resulting in a failure to recognize the distance to the runway and altitude relative to the rising terrain.

Figure 3: Most Frequent Factors in F-16 Class A Mishaps



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

manage the immediate situation as perceived by the individual.

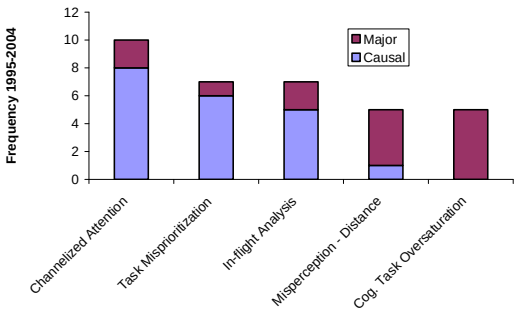
Risk Assessment is a factor when the individual fails to adequately evaluate potential risks associated with a selected course of action and this failure leads to an unsafe situation. Behaviors labeled *risk assessment* varied greatly across accidents.

Cognitive task oversaturation occurs when the quantity of information to process exceeds a person's cognitive or mental resources, resulting in a loss of SA.

Specific A-10 CRM Factors. The five leading human factors cited in A-1- mishaps are depicted in Figure 4. The top two were directly related to the CRM areas of dimensions of SA and task management. Definitions were discussed in the previous section. The third element, in-flight analysis, refers to a failure to analyze an in-flight situation to the extent normally expected which leads to degraded performance. This factor was assigned to the *decision making* area of CRM in our quantitative analyses. Misperceived distance and cognitive task oversaturation round out the top five. Both factors were described in the preceding section. Consistent with the overall CRM patterns in A-10 mishaps discussed earlier, these specific underlying CRM-related factors reflect problems with SA, task management, and decision making.

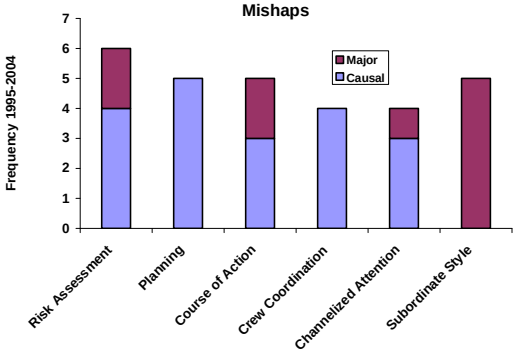
Two hazardous attitudes, overconfidence and complacency, were in the top ten factors. AFI 11-290 places such factors under crew coordination/flight integrity.

Figure 4: Most Frequent CRM Elements in A-10 Class A Mishaps



Specific C-130 CRM Factors. The top individual CRM-related factors in C-130 mishaps from 1995 through 2004 are summarized in Figure 5. There was a two-way tie for the fifth factor between channelized attention and subordinate style--both are presented and discussed.

Figure 5: Most Frequent CRM factors in C-130 Class A Mishaps



Two factors, risk assessment and channelized attention were discussed in earlier sections. *Flight planning* is a factor when proper flight planning for the mission is not accomplished. In most of these mishaps, other military duties competed with planning activities, resulting in the crew failing to access accessing available, crucial information. *Course of action selected* is a factor when the wrong course of action is selected through faulty logic and decision making. Several instances originated in planning due to inadequate gathering of data that was readily available (e.g., terrain, weight of cargo, or weather). Other instances involved less-than-ideal responses to in-flight equipment problems.

Crew Coordination is defined as the lack of a systematic division of subtasks between crew of flight members to accomplish a larger task more efficiently. Behaviors leading to this factor being cited included lack of cross-check, failure to provide feedback, lack of input, not catching checklists that were started but not completed, failure to delegate backup responsibilities, and lack of a symmetrical division of tasks within the cockpit.

Subordinate style/copilot syndrome refers to the basic belief by an aviator that someone else (other crewmembers or individuals external to the aircraft) have the situation under control and are looking out for their best interest. Several instances involved a well respected individual on the crew with whom others felt they did not need to be directive, resulting in some crewmembers taking themselves out of the decision process. Other mishap involved misplaced trust in planners or air traffic control.

The CRM-related causal or contributing factors cited in C-130 mishaps were consistent with the AFI 11-290 set of six core CRM areas. Four of

the six areas were included in the top six factors. All six were represented in the top ten with the inclusion of intracockpit communication and necessary action delayed (a task management factor).

Commonalities and differences across platforms

Human factors remained prominent in recent F-16, A-10, and C-130 Class A mishaps. Further, the most frequency cited human factors were consistently CRM-related. As a result, CRM skills remain great targets of opportunity for reducing preventable mishaps in all three platforms. SA, task management, and risk management/decision making factors were evident across all three air frames.

The relative contributions of the remaining core CRM areas, however, appeared to differ substantially across air frames. Human factors related to *crew coordination/flight integrity* were more common and central in C-130 mishaps than were factors in any other CRM area. The problems revolved around interpersonal interactions--failure to back up other crew members or question an unsafe condition or action. The crew coordination/flight integrity factors for both F-16 and A-10 are limited to hazardous attitudes—overconfidence, complacency, invulnerability, and get-home-it is.

Mission planning was causal in the majority of C-130 mishaps included in this analysis, yet pre-mission planning was never cited in either F-16 or A-10 mishaps. The small presence of mission planning in F-16 mishaps came from a single instance of faulty in-flight replanning.

Communication was the least frequently cited CRM area in all three air frames. Intracockpit communication was the leading C-130 communication problem. Misinterpreted communication and external communication. Were occasional problems in all three aircraft.

Conclusions

First and foremost, the most frequently cited causal and major contributing factors to flight mishaps in the mishap reports that we reviewed were consistently CRM-related. The six core CRM areas in AFI 11-290 are broad enough to cover at least the most frequently cited factors. In single seat aircraft, some CRM areas do not appear to be as problematic as others. Specifically, mission planning, communication, and flight integrity are seldom cited as causal or major contributing factors in A-10 and F-16 mishaps. The remaining core CRM areas (SA, task management and risk assessment/decision making are areas that will need to be improved if mishaps are to be reduced. Even within these core CRM areas, the majority or problems are clustered in a few factors. As a result, we can be very prescriptive concerning areas in which improvement should impact mishap rates.

The bottom line is that AFI 11-290 defines a sound domain for CRM training, but our data suggest that, at least for single seat aircraft, attending to a few particularly troublesome areas could pay big dividends.

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