Human Factors in Air Force Flight Mishaps: Implications for Change

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ABSTRACT

Each service expends considerable effort to document human factors that cause or contribute to flight mishaps. One goal of this activity is to avoid repeating the same mistakes with the same undesired outcomes. The service safety centers generate mishap-related reports at several levels of granularity. In the Air Force, mishap summaries are routinely distributed and reviewed for applicability to academic or simulator training in accordance with the instruction that specifies Cockpit/Crew Resource Management (CRM) training. More detailed information regarding pilot/crew behavior exists in a Safety Center human factors database, and even more detailed information resides in Mishap Investigation Board reports. These more detailed data were rarely analyzed for training purposes in the past, but that is beginning to change. Detailed analyses of all human factors were recently completed for recent C-130, MH-53, F-16, and A-10 Class A mishaps. Pilot/crew error was causal in most. The most frequently cited factors usually corresponded to traditional CRM areas. All six Air Force CRM areas were frequently cited in tactical airlift mishap factors. However, only three CRM areas were frequently cited in F-16 and A-10 mishaps (situation awareness, task management, and risk assessment/decision making). The remaining areas were rarely mentioned. We describe our analytic approach, which addresses both frequency and severity of factors cited, and includes both quantitative and qualitative analyses. We also describe commonalities and differences across aircraft types and discuss underlying behaviors. The detailed information in human factors databases and formal mishap reports provide a robust bridge between mishaps and training that is often missing today. Our analytic approach builds on considerable work already accomplished by mishap investigation boards. Applications-to-date include tailored material for C-130 and A-10 mission qualification training and annual refresher CRM courses, and validating key CRM areas in a new Department of Defense human factors analysis and classification system.

ABOUT THE AUTHORS

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INTRODUCTION

A challenge from Secretary Rumsfeld to reduce preventable mishaps by 50% (Rumsfeld, 2003) has generated considerable interest within the Department of Defense (DoD) to understand why mishaps occur and to develop effective mitigating strategies. The human and fiscal costs associated with aircraft mishaps make them a highly visible part of the safety equation, and as a result, a joint service Aviation Safety Improvement Task Force was established to develop a unified approach for meeting the Secretary's challenge in this particular area.

The central role of human error in flight mishaps is well documented. For example, Helmreich and Fouchee (1995) reported that flight crew actions were <u>causal</u> in more than 70% of worldwide air carrier accidents from 1959 to 1989 involving aircraft damage beyond economic repair. Luna (2001) reported that human factors were major contributors or causal in over 60% of Air Force Class A mishaps and over 90% of fatal mishaps from 1991 to 2000 with little change over that time period.

In a review of seven Canadian Air Force CC-130 mishaps that occurred from 1980-1993, Hendy, Thompson, Fraser, Jamieson, Comeau, Mack, Paul, and Brooks (1998) reported that human factors issues were implicated in each. The majority of mishaps involved a breakdown of crew coordination, and decision making was such a central problem area that the Canadian study team recommended replacing their aircrew coordination training (ACT) program with decision-centric human factors training (Hendy and Ho, 1998).

In a review of Air Force C-130 Class A mishaps that occurred from 1992-2002, Nullmeyer, Stella, Flournoy, and White (2003) found very similar patterns. Causal Crew Resource Management (CRM) factors were common. Risk assessment or decision making factors were cited in 93% of these mishaps.

These consistent findings suggest that an effective response to Secretary Rumsfeld's challenge must address human factors problems, and that CRM-related issues are likely to dominate the list of problems that need to be solved. A joint service Human Factors Working Group (HFWG) was established as a critical part of the Aviation Safety Improvement Task Force. HFWG goals included identifying common human factors hazards across services and developing shared mitigating strategies. The HFWG reviewed several dozen recent mishap reports in the past year from all military services. Consistent with earlier research findings, this review revealed that human factors remain prominent as causal or contributing factors.

One early HFWG task was to develop a joint service Human Factors Analysis and Classification System (HFACS) for use in mishap investigations throughout the DoD. This project included developing a joint service definition of CRM. Comparisons among Air Force, Army, Navy, and Coast Guard CRM programs revealed different CRM skill categories but surprisingly common underlying content. Six common skill areas emerged: situational awareness, decision making, mission analysis, task management, communication, and team coordination. These legacy DoD CRM areas are distributed throughout the new HFACS structure, so a map was developed that connects relevant HFACS elements with appropriate CRM areas. Using this mapping, CRM elements emerged as salient human factors in the HFWG review of military mishaps.

It may be useful to consider lessons learned in commercial aviation regarding CRM training. Helmreich, Merritt, & Wilhelm (1999) documented a progression of CRM training philosophies and goals through four distinct generations. They concluded that the original safety-related goals of CRM appeared to have become lost on many CRM training participants and proposed a fifth generation to explicitly refocus CRM training on error management.

Helmreich, Wilhelm, Klinect, and Merritt, (2001) studied threats to safety and the nature of errors in three airlines. Striking differences were observed among these airlines regarding both threats and errors. Helmreich and his colleagues concluded that individual air carriers cannot assume that their training requirements will correspond to normative data from the industry, and proposed a sixth generation of CRM that adds the need to understand an organization's threats to safety to the previous domain of error management. The authors maintain that organizations must have current and accurate data regarding the true nature of threats and errors to shape effective training content and structure assessments of training impacts. Helmreich, et al. (1999) discussed five data sources: 1) formal evaluations of flight crews; 2) incident reports from aviators; 3) surveys of flight crew 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.

Mishap reports were not included in this list due to the very low numbers of mishaps involving commercial air carriers. Given the substantial numbers of human factors-related mishaps in military operations, however, it only makes sense to learn about threats and error from this data source as well. Our goal in this paper is to distill needs for change from human factors trends in C-130, MH-53, F-16, and A-10 mishap reports, including commonalities and differences across platforms. Our scope includes all human factors cited in operations-related mishaps involving these four platforms from 1995-2004.

Although our focus in this paper is on mishap data, we recognize that mishap reports are not sufficient by themselves to structure training, even CRM training. Maurino (1999) correctly stated that if we only look at accidents, we only learn about CRM failures. In addition, Dekker (2003) described several potential problems associated with over-reliance on human error taxonomies, including risks associated with removing the context that helped produce the error.

Such concerns imply that mishap human factors trends must be viewed in the context of other information to develop truly robust training interventions that are likely to impact safety and effectiveness. The data sources recommended by Helmreich et al. (1999) have considerable merit. Following a similar multi-source logic, our review of C-130 mishaps was augmented with analyses of instructor comments in student records and with expert assessments of the CRM behaviors exhibited in annual simulator training as part of a recent project to readdress CRM training for tactical airlift crews (Wilson and Deen 2003). These additional data sources 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 demanding simulator scenarios.

METHODS

Mishaps Reviewed

The analyses reported here addressed C-130, H-53, F-16, and A-10 Class A mishaps (aircraft destroyed, $1 million damage, or fatality) from FY95 through FY04 that the Air Force Safety Center determined to be operations-related. The numbers of mishaps were:

10 C-130 mishaps, 9 operations-related
14 H-53 mishaps, 10 operations-related
75 F-16 mishaps, 36 operations-related
20 A-10 mishaps, 19 operations-related

The mishaps that were not operations-related usually involved an equipment failure that could not be resolved by the pilot or crew. In three of the four platforms, there were few such instances. In the F-16 community, about half of the Class A mishaps during the last decade involved engine failure.

Mishap Data Sources

The Air Force Safety Center documents Class A mishaps at varying levels of granularity. The analyses reported here combine information from two sources. A detailed **Human Factors Database** was populated and maintained by Air Force Safety Center Life Sciences Division analysts using the *Mishap Human Factors Taxonomy* to structure findings regarding the roles played by operators, maintainers, and other personnel in each Class A mishap. This taxonomy divides human factors into two major branches--environmental or individual factors. These two branches are further subdivided as shown in Figure 1.

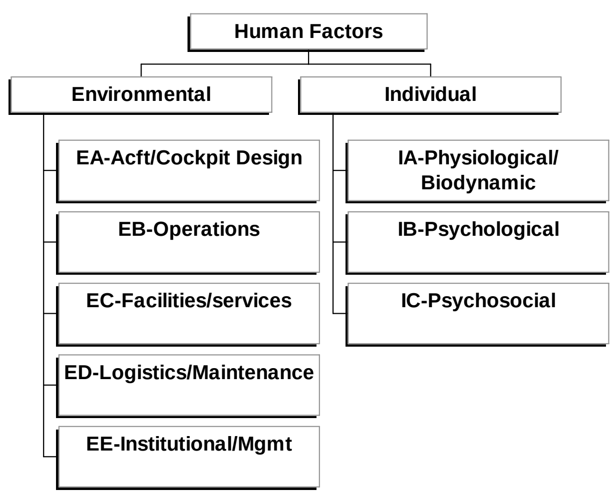

Figure 1: Mishap Human Factors Taxonomy

Each of these areas is, in turn, further divided into sub-areas. For example, the area labeled "Operations" is divided into preparation, cockpit/crew resource management, procedural guidance/publications, and mission demands. Finally, several elements comprise each sub-area, resulting in over 380 detailed elements. Safety Center analysts assigned weightings to each human factors element cited using the following scale: (4)-causal; (3)-major contributor, (2)-minor contributor, (1)-minimal contributor, or (0)-present but not a factor.

A **Life Sciences Report** is part of each Air Force Safety Center's full Class A Mishap Investigation Board report. It provides a chronological mishap narrative and a discussion of every element cited in the human factors database. Interrelationships among the human factors may be addressed. These discussions are essential for understanding the behaviors underlying the human factors data base trends.

The human factors database serves a function similar to the electronic catalog at the library. The Life Sciences Reports are the books. There is considerable risk of misinterpretation if database quantitative analyses are accomplished without reviewing the descriptive content of the associated Life sciences reports.

Analytic Approach

Our initial quantitative analyses of human factors database entries addressed frequencies of occurrence and levels of contribution associated with each detailed human factors element that was cited in operations-related C-130, H-53, F-16 and A-10 Class A mishaps over the past decade. These data were analyzed separately for each platform. In C-130 and H-53 mishap reports, individual crewmember human factors were combined to generate a single crew-level set of factors with weightings for a given mishap. Sums of weighted factors (e.g., 4=causal) were calculated across mishaps for each element cited and used to rank-order the individual elements. Discussions in the Life Sciences Report were then analyzed to gain a better understanding of the underlying behaviors that led to each element being cited.

Next, we specifically addressed the role of factors comprising the six DoD CRM areas in these modern mishaps. The Mishap Human Factors Taxonomy was first reviewed to identify CRM-relevant elements using the CRM mapping that was developed for the HFWG. Individual elements were grouped with other related elements within the each of the six CRM areas allowing us to assess the relative contribution of each CRM area to mishaps in the context of all human factors. About sixty of the 380+ detailed taxonomy elements were determined to be CRM-related. These 60 elements were mapped into the six proposed DoD CRM areas as follows:

- Perceptual and attention management elements were mapped into <u>situation awareness</u> (SA);
- <u>Task management</u> (TM) factors included procedural elements, task misprioritization, and cognitive task oversaturation;
- <u>Decision making</u> (DM) elements came primarily from the judgment and decision making node of the mishap taxonomy and included risk assessment;
- In-flight analysis and in-flight planning were added to pre-mission planning and briefing factors to comprise <u>mission analysis</u> (MA);
- <u>Communication</u> (Com) was a preexisting node in the mishap taxonomy that encompassed both intra-cockpit interactions and interactions with external to the aircraft.
- Elements of the <u>team coordination</u> (TC) node included leadership, subordinate style and crew coordination factors. Hazardous attitude elements that influence team interactions such as complacency and subordinate style were also included here.

RESULTS

C-130 Mishap Human Factors

A rank ordered list of all C-130 human factors was generated based on the frequencies with which each was cited, weighted by the associated contribution scores listed in the human factors database. C-130 mishap human factors were highly localized in the taxonomy—of more than 380 possible factors only 60 were cited at all in the past decade.

The ten most frequently cited human factors in C-130 mishaps from 1995 through 2004 are shown in Table 1 in descending order of weighted frequency. This table shows the frequency with which each factor was cited as being causal, a major contributor, or a contributor at any level. Eight of the top ten factors were cited as causal or major contributing factors in over half of the C-130 mishaps in the past decade suggesting that these areas may represent opportunities to notably decrease C-130 mishap frequencies. Of some note, all six of the proposed DoD CRM areas are represented at least once in the top ten factors. Seventy two percent of all contribution-weighted factors corresponded to the DoD CRM skill categories.

<u>Risk Assessment</u> was the most frequently cited human factor, was causal in 4 of the 9 C-130 Class A mishaps,

and contributed to four others. A review of Life Sciences Report discussions revealed that underlying behaviors included both lack of deliberate risk assessment during pre-mission planning and lack of real-time risk assessment inflight when an external event forced a deviation from the original plan. *Course of action selected*, in turn, was causal or a major contributor in six of the nine mishaps, and cited without risk assessment in only one mishap.

Table 1: C-130 Mishap Factors 1995-2004 (n=9)

Factor	Cause	Major	All
Risk Assessment (DM)	4	2	8
Written Procedures	3	3	6
Course of Action (DM)	3	2	6
Flight Planning (MA)	5		5
Channelized Attn. (SA)	2	3	5
Subordinate Style (TC)		5	5
Action Delayed (TM)	3	1	5
Crew Coordination (TC)	4		5
Intracockpit Comm (Com)	2	2	4
Complacency (TC)	3		4

Inadequate written procedures included aircraft checklists, technical orders, and command procedures. This was a major or causal factor in most C-130 mishaps in the past decade. Airlines are investing resources in this area to standardize procedures across crews. The frequency of this factor being cited in C-130 mishaps suggests that there may be considerable potential to reduce aircraft accidents with improvements in this area. Leadership has to be proactive in changing needed procedures, then enforcing and creating an atmosphere for a culture change. This is a broad area to address and changes must come from the top down. Some opportunities to reduce C-130 mishaps may be as simple as revisiting checklist design, timing, layout and ease of use.

Flight Planning was causal in the majority of C-130 Class A mishaps, and is a factor when proper flight planning for the mission is not accomplished. Planning as a causal factor increased over the time period analyzed. In several mishaps, other military duties competed with planning activities, resulting in the crew failing to access and incorporate available, crucial information. In others, people other than the crew developed the plan. In either case, the result was a crew with an incomplete mental model of mission requirements and constraints.

Channelized Attention was a major contributor or causal in 5 of the 9 C-130 Class A mishaps. Channelized attention is a factor when conscious attention is focused 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.

Factors related to team dynamics were causal or major contributors in seven of the nine mishaps reviewed. *Crew Coordination* was cited as a causal factor in 4 of the 9 mishaps, usually in response to a failure to back up other crewmembers or challenge a questionable decision. *Subordinate style/copilot syndrome* and the highly related *complacency* were collectively cited as being causal in three of the mishaps and contributing to four others, usually involving 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 mishaps involved misplaced trust in planners or air traffic control. Lack of *intracockpit communication* was often a physical manifestation of subordinate style and complacency.

Interrelationships among factors that were described in many of the Life Sciences Reports demonstrate that the mishap human factors do not operate independently. Figure 2 depicts an attempt to capture the underlying structure. The mission timeline progresses from left to right. In most of C-130 mishaps reviewed, an unforeseen external event required the crew to deviate from the plan as written. The crew response was usually causal to the subsequent mishap. Starting on the right hand side, the behaviors immediately preceding the mishap were risk assessment and the course of action selected (Decision Making) in response to this event. These two were co-cited as causal or contributing factors in all but one mishap. Incomplete SA was also cited in each of these mishaps. Reports often address how inadequate SA contributed to the reduced quality of subsequent risk assessment and decision making.

The shaded area in the center of Figure 2 encompasses teamwork and task management factors, core areas in many CRM training programs (Salas, Rhodenizer, and Bowers, 2000). They apply throughout planning as well as mission execution. In mishap reports, inadequate teamwork usually contributed to incomplete SA during the execution phase. Crew coordination, subordinate style and complacency were factors in 7 of the 9 mishaps reviewed. In too many C-130 mishap reports, one crewmember possessed critical information regarding the event that triggered the mishap, but that information was not incorporated into the course of action selected by the primary decision maker, usually the pilot flying.

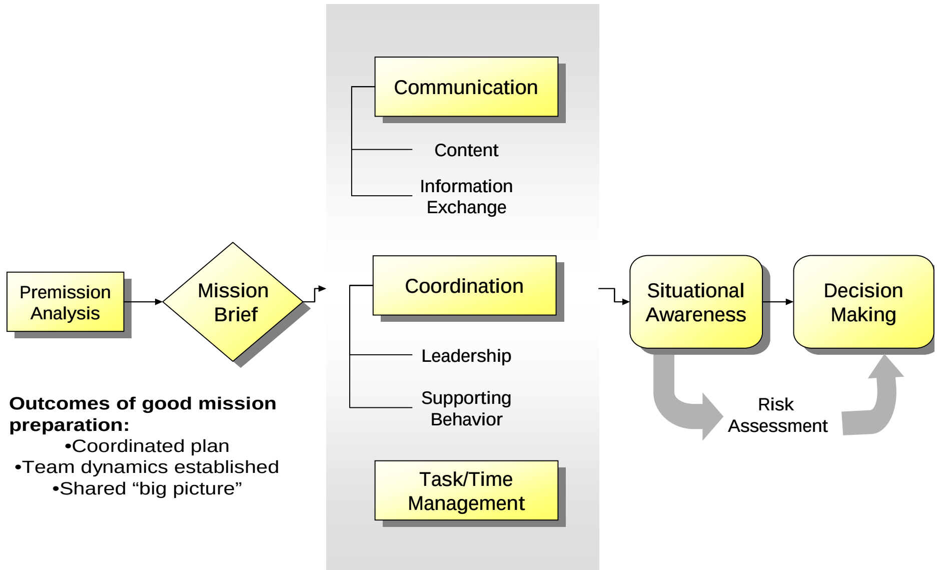

Figure 2: Temporal Relationships among C-130 Mishap Human Factors

Communication in this model refers to properties such as accuracy, clarity, content, completeness and timelines of information passed. These definitions are borrowed from the Navy's Team Dimensional Training model (Smith-Jentsch, Zeisig, Acton, and McPherson, 2000). Communication factors occasionally referred to less than ideal cockpit intercom technology but most often reflected lack of verbal input. Task management rounds out this section, and was often a factor in pre-mission activities which are depicted on the left side of Figure 2.

Most C-130 mishaps in the past decade were preceded by planning and briefing shortfalls that were cited as causal to the subsequent mishap. Of some concern, the frequency with which these factors are cited appears to be increasing over time. Problems fell into two areas—crews were occupied with other job-related activities and devoted insufficient time to information collection, mission analysis and briefing, or someone else did the pre-mission analysis leaving the flight crew with little knowledge for replanning when the original plan is blocked. Spiker, Wilson and Deen (2003) documented several pre-mission behaviors that were uniquely exhibited by highly effective C-130 tactical airlift crews. All crews developed a reasonable mission folder. In superior crews, healthy team dynamics were overtly established. For example, inputs were actively sought and rewarded. Finally, commanders of superior crews conducted a final crew huddle at the planning table to review the mission, note the high risk areas and build a shared "big picture."

H-53 Mishap Human Factors

A rank ordered list of all H-53 human factors cited in Class A mishap reports was generated with factors weighted by degree of contribution. The analytic process was identical to the one described above for C-130 factors. H-53 mishap human factors were again highly localized in the taxonomy—of more than 380 detailed elements, the top 10 accounted for almost half (48%) of all weighted scores.

The top ten H-53 human factors are listed in Table 2. The DoD CRM skill areas are indicated in parentheses when appropriate. In general, fewer human factors elements were cited in H-53 mishaps than the other three platforms. Still, 70% of the mishap reports cited the presence of two or more causal factors.

Table 2: H-53 Mishap Factors 1995-204 (n=10)

Factor	Cause	Major	All
Over/Undercontrol	4		4
Risk Assessment (DM)	3	1	4
Written Procedures	3		4
Overconfidence		3	5
Total Experience		2	5
Inflight Analysis (MA)	1	1	4
Vision Deficit (SA)	1	2	3
No Training for Task	2		3
Visual Illusion (SA)		3	3
Vision Restricted (SA)	2	1	3

Skill-based factors were unusually prominent in H-53 mishaps compared to the other platforms. *Overcontrol/ Undercontrol* of the helicopter emerged as the highest ranked human factor, cited as causal in four of the ten mishaps that occurred in the past decade. *Limited total experience* was a contributing factor in half of the mishaps in the period analyzed. *No training for the task accomplished* also made the top ten list. Overcontrol/undercontrol was consistently accompanied by a visual factor indicating limited SA—visual misperception or visual limitation.

Behaviors behind the risk assessment element included the failure to consider multiple emerging environmental factors, not comprehending the gravity of the situation, and waivers becoming routine. Inadequate written procedures were causal or contributed to three mishaps in the early part of the time period of this analysis. Overconfidence was a contributing factor in half of the mishap reports, and was associated with a highly experienced crew flying a seemingly routine mission, attempting more rapid iterations based on lack of difficulty in previous maneuvers, and flying into an unrecoverable situation without assessing the situation. These tended to be factors in mishaps that occurred early in the decade. Finally, inflight analysis tended to involve the failure of a crewmember to recognize the need for a specific action given changing circumstances.

Across all human factors weighted for degree of contribution to the mishap, 64% of H-53 factors involved legacy CRM skills. The legacy CRM factors cited in the H-53 mishaps are consistent with the model in Figure 2, focusing primarily on the right hand side of the sequence with risk assessment and mission analysis being hampered by being unaware of critical information. However, four factors not traditionally addressed in legacy CRM programs also appeared in this top 10 list (over/undercontrol, written procedures, limited overall experience, and no training for task attempted).

F-16 Mishap Human Factors.

Fewer than 80 of the 383 available human factors elements were cited at any level in F-16 mishap reports from 1995 through 2004. Forty seven percent of elements weighted for degree of contribution were concentrated in the ten factors shown in Table 3.

Channelized attention is an extremely common factor in F-16 mishaps, cited as causal in 14 mishaps and contributing to 13 others, with this one factor affecting over 75% of the mishaps reviewed. Failure to maintain appropriate visual scan is by far the most frequent problem cited. Recent examples included attending to broken equipment inside the cockpit during low level flight, target fixation, and relying exclusively on radar while ignoring all other instruments, and failure to attend to the distance to the runway or altitude relative to the rising terrain. *Task Misprioritization* behaviors included initiating a dive recovery too late and inappropriately expediting tasks due to limited fuel remaining.

Misperceived distance and to a lesser extent, *misperceived speed* combined were rated as causal or contributing to over half of Class A mishaps in the past decade. Other frequently cited factors were *Risk Assessment, unrecognized spatial disorientation, cognitive task oversaturation, course of action selected, wrong technique*, and distraction. Overall, legacy CRM areas were well represented in the top ten F-16 mishap human factors. More generally, CRM-related factors accounted for 63% of all factors weighted for level of contribution to the mishap.

Table 3: F-16 Mishap Human Factors (n=36)

Factor	Cause	Major	All
Channelized Attn (SA)	14	10	27
Misprioritize Task (TM)	12	4	18
Misperceive distance (SA)	7	7	16
Risk Assessment (DM)	6	5	14
Spatial D -- Type 1	6	6	13
Cog. Task Oversat. (TM)	3	7	11
Course of Action (DM)	5	3	9
Wrong Technique	7	1	9
Distraction (SA)	4	3	10
Misperceive speed (SA)	4	2	10

A-10 Mishap Human Factors

Patterns among A-10 mishap human factors were highly similar to the patterns addressed in F-16 mishap reports. Factors were again concentrated in a few areas, with fewer than 60 of the 383 human factors elements cited. The top 10 leading human factors in A-10 mishaps are depicted in Table 4. These ten factors accounted for nearly half (46%) of all factors weighted for degree of contribution.

The top two human factors in A-10 mishaps (*Channelized attention* and *task misprioritization*) are identical to the top two mishaps for operations-related F-16 mishaps, and were discussed above. 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. Event proficiency and limited experience, two non-legacy CRM factors, round out the top 5.

Table 4: A-10 Mishap Human Factors (n=19)

Factor	Cause	Major	All
Channel. Attn. (SA)	7	2	11
Misprioritize Task (TM)	6	3	9
Inflight Analysis (MA)	4	4	8
Event Proficiency		5	7
Limited Experience	1	3	6
Cog. Task Oversat. (TM)	0	4	6
Misperceive Distance (SA)	1	3	5
Course of Action (DM)	3		4
Inattention (SA)	2		4
Spatial D. -- Type 1	3		3

Commonalities and Differences across Platforms

Human factors in all four aircraft types remained prominent in operations-related Class A mishaps from 1995-2004. The factors cited represent a relatively small subset of all elements in the Mishap Human Factors Taxonomy. Less than 25% of the 380 possible factors were used in any of the four platforms reviewed, and within those, the majority of factors cited were concentrated in the top 10 to 23 detailed elements, depending on the platform.

As can be seen in Tables 1-4, the vast majority of the frequently cited factors appear to be in areas for which training is a logical intervention strategy. Factors corresponding to the six DoD CRM areas still dominate the human factors elements cited in all four aircraft typed analyzed (72% of C-130 factors, 64% of H-53 factors, 63% of F-16 factors, and 68% of A-10 factors, all weighted for degree of contribution to the mishap). Our assignment of frequently-cited factors to CRM areas is indicated in parentheses following factors in Tables 1-4.

Every human factors-related mishap involved multiple CRM factors that formed classic error chains. There were no single-factor mishaps. In C-130 mishaps, these chains sometimes stretched from choosing an unfortunate course of action just before the mishap all the way back to insufficient pre-mission analysis by the crew that resulted in incomplete SA that in turn resulted in incomplete risk assessment as intermediate links of the error chain. The chains tended to be truncated in single seat aircraft mishaps, but even in these platforms, faulty task prioritization was associated with channelized attention in most cases, and selecting the wrong course of action was consistently accompanied by channelized attention or misperception.

While the dominance of CRM-related factors in mishaps was common across aircraft types, the specific CRM areas that were frequently cited varied considerably across some platforms. Figure 3 depicts the proportions of mishaps by aircraft type in which each CRM area was cited as a causal or major contributing factor. Even at this summary level, differences are apparent between fighter and attack aircraft on one hand and tactical airlift aircraft on the other. SA was frequently cited as a causal or major contributing factor in all four platforms, as were task management and risk management/decision making factors. The relative contributions of the three remaining core CRM areas, however, appeared to differ substantially based on aircraft type. Factors related to coordination, communication, and planning were much more common and central in C-130 mishaps than in F-16 and A-10 mishaps. Proportions of factors cited across the six DoD CRM areas were virtually identical in A-10 and F-16 mishaps.

Detailed human factors contributing to these summary proportions remained remarkably stable within aircraft types. Evidence of this stability can be seen in Tables 1-4 from the frequency with which specific factors were cited in more than 50% of the mishaps. This was especially frequent in C-130 mishaps where eight of the top ten detailed factors were cited in the majority of Class A mishaps.

Patterns of factors across aircraft types, however, were often quite different. The most frequently cited F-16 and A-10 factors were channelized attention and task misprioritization, representing SA and task management CRM areas. Coordination factors in both F-16 and A-10 mishaps are infrequent and the few that appear in Figure 3 reflect complacency. The C-130 factors most frequently cited as causal were flight planning, risk assessment, and coordination--failure to back up other crew members, often in the form of failure to question an unsafe condition or action. The leading causal factor for H-53 mishaps was overcontrol/undercontrol, a non CRM-related problem. *Communication* was the least frequently cited CRM area in all four airframes, although intracockpit communication remains problematic in most C-130 mishaps, where the lack of communication was closely related to inadequate coordination.

Mission Analysis factors were causal in the majority of C-130 mishaps. More specifically, the factors cited in this area for tactical airlift mishaps referred to inadequate pre-mission planning and briefing by the crew due either to competition from other duties or to complictions associated with having other people doing

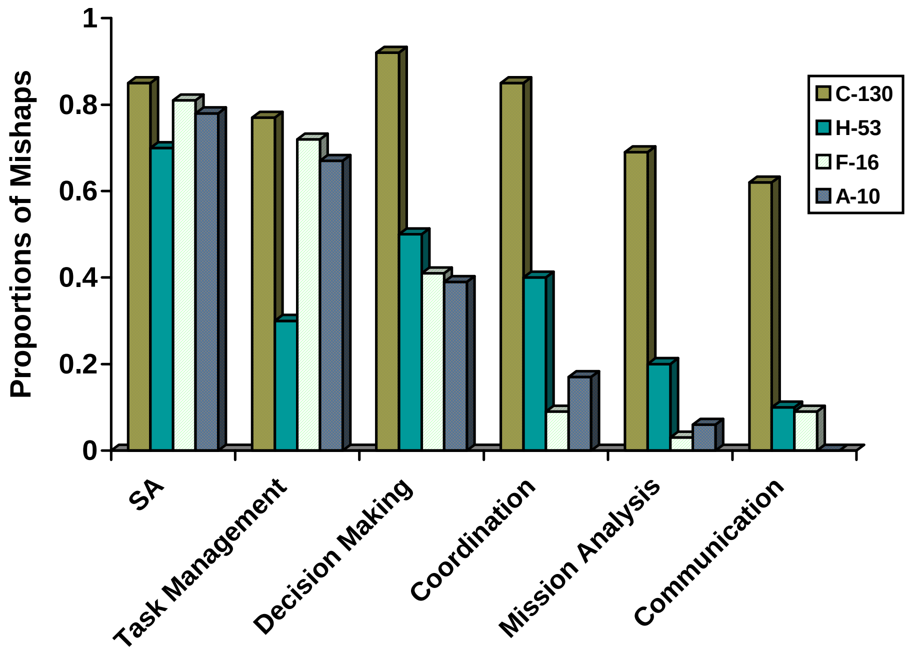

Figure 3: Proportions of CRM-related Factors in Recent Class A Mishaps

much of the pre-mission information collection and analysis. In contrast, pre-mission activities were never cited in H-53 or F-16 mishaps and cited only once in A-10 mishaps. The mission analysis factors in H-53 and A-10 mishaps represented in-flight analyses immediately preceding the mishap event.

IMPLICATIONS FOR CHANGE

Over 60% of all mishaps across the four aircraft types were caused by human error, and if F-16 engine failures are not counted, that figure increases to over 85%! Of some note, F-16 engine-related Class A mishaps dropped by 50% from 2000-2004 relative to 1995-1999 while human error mishap frequencies remained unchanged. Clearly, Secretary Rumsfeld's 50% mishap reduction challenge simply cannot be met without addressing pilot/crew error.

Several major human factors trends emerged from the detailed mishap factor data. First, the six CRM areas that were distilled from legacy CRM or ACT definitions continue to dominate the human factors cited in modern military mishaps. Given the high frequency and importance of CRM factors across all four aircraft types, we conclude that the current approach to CRM training needs to be revisited. Second, there were substantial differences across aircraft types regarding both the breadth of CRM areas cited in mishap reports and the specific underlying factors within those areas. Within aircraft types, however, mishaps tended to reveal repeating chains of events across mishaps, suggesting that effective aircraft-specific training interventions can be established, but that these will vary by platform.

Helmreich and his colleagues (2001) concluded that, to be effective, CRM training must be based on information from a robust data collection and assessment system with elements such as Line Operations Safety Audits (LOSA) and Flight Operations Quality Assessments (FOQA). We concur. We feel that mishap reports represent an important addition to LOSA and FOQA to paint an accurate picture of CRM performance by military aviators, thus allowing training developers and providers to produce training that meets specific and actual needs.

To understand the connection between robust threat and error data and the practice of "training" CRM skills, consider the following basic instructional systems design (ISD) feedback loop:

Performance data →
Training content →
Trainee performance →
Performance data.

In this model, data describing crew performance drives the design and content of CRM training. The CRM training program is designed to equip crews with specific CRM skills to improve performance. That performance is assessed by means of data collection and analysis to paint an accurate picture of the observed performance. The data describing observed performance is then fed back into the ISD process, thus closing the tight feedback loop.

The model fails when any element of the "loop" is ineffective. For example, if vague or inaccurate data is fed into the ISD process, flawed and ineffective training results. Human factors trends from mishap reports have the potential to feed a more accurate picture of observed performance into the ISD process. This ensures that specific CRM skills, targeting specific performance deficiencies, are trained and allow crews to correct performance shortfalls. One CRM training vendor explains the concept with this metaphor: "No matter how highly crafted the rifle (the training program), if you shoot in the dark (inaccurate performance data), you rarely hit anything (correct and improve performance)." This analysis of mishap factors "lights up the darkness", allowing targeted CRM performance improvements.

With this new, brighter light, what do we see? No surprise here, but performance in different weapon systems can reflect very different threats/risks to which crews are exposed and also very different responses to those threats/risks. C-130 crews face different threats than do F-16 pilots and require a different set of skills to overcome those threats. Our data clearly show that fighter pilots would benefit from training that emphasizes proper task prioritization and ways to avoid channelized attention. C-130 crews would benefit from improved decision making, risk assessment and coordination in both mission planning and execution.

These analyses demonstrate the value of mishap data to help define CRM training content, but mishap trends will not suffice as stand alone data. Additional data sources need to be developed. We currently document very little regarding CRM-related behaviors. More effective training for Instructors and Evaluators (I/E) to brief, observe, assess, debrief and document CRM performance by aircrews could pay big dividends. Currently I/Es receive a "one-time, good for your career" Instructor course in CRM. As training programs are improved based on the observed performance data, I/Es will need more training to be able to instruct and assess the discreet observable CRM behaviors that emerge. Without continued training on evolving CRM skills, I/Es will become a weak link in the training feedback loop and cause the model to fail.

Unfortunately, the Air Force Instruction governing the conduct of the CRM training program is a one size fits all document dictating the core CRM curriculum. This lock step approach does not allow training providers the necessary flexibility to re-engineer the skills covered in the curriculum based on data such as the patterns revealed in this study. Training resources, including both aircrew time and training costs, are especially precious during this budget busting war on terror. CRM training targeted to specific needs is imperative.

This is not just an Air Force condition. A joint service, military/industry CRM working group was established to revisit CRM training across the DoD. The group concluded that all service CRM training regulations are outdated with none addressing fifth or sixth generation CRM concepts. CRM working group conclusions and recommendations parallel the conference theme "One team, One fight, One training future." Increasing use of joint service school houses and joint operations add value to a joint service approach to replace the current service-unique ways to define CRM (the Air Force's six CRM curriculum areas, the Navy's seven deadly sins, and the Army's 13 basic qualities). The CRM working group is advocating a DoD CRM training model to increase consistency in training across the services and facilitate sharing of successful training strategies across applications.

Finally, if the goal of the CRM training program is to improve performance and thus reduce accidents and improve mission accomplishment, then better data is clearly needed to guide that training. The analyses reported here provide a method for mining training needs data from mishap reports and the results demonstrate the value of doing so. Other data sources also have merit. Now, military CRM training organizations need to: (1) base CRM training content on more robust data rather than generic, service-wide topic lists to guide, (2) allow training providers to fully utilize that data in redesigning their CRM programs, (3) require recurrent/ refresher I/E CRM training and (4) standardize CRM concepts, terms and training strategies across the services.

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