Presented at the 11th International Symposium on Aviation Psychology.
Columbus, OH: The Ohio State University. 2001.

AIR TRAFFIC CONTROL (ATC) RELATED ACCIDENTS AND INCIDENTS: A HUMAN FACTORS ANALYSIS

Anthony M. Pape and Douglas A. Wiegmann
Institute of Aviation
University of Illinois at Urbana-Champaign
Savoy, IL

Scott Shappell
Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, OK

ABSTRACT

To date, the nature and role of ATC personnel in aviation accidents and incidents has yet to be fully examined. To remedy this situation, a comprehensive review of ATC-related accidents and incidents that occurred between January 1985 and December 1997 was conducted using records maintained by the NTSB. Results of the analysis revealed that ATC-related accidents and incidents are infrequent events. However, when these events do occur they are likely to involve local controllers interacting with multiple aircraft in the air during daylight VFR conditions. An in depth analysis of the narrative reports using the Human Factors Analysis and Classification System (HFACS) revealed that skill-based errors (attention failures and memory lapses) were the most common type of error committed by ATC personnel. Supervisory and organizational factors such as controller training, procedures, and oversight were cited in only a small fraction of the incident and accident reports. However, current accident and incident reporting systems were not designed with ATC errors in mind, making the analysis of latent factors, such as supervisory and organizational issues, extremely difficult. What is needed is a new error-analysis framework that will facilitate the gathering of information during ATC-related accident and incident investigations.

INTRODUCTION

Human error has been cited as a major factor in the majority of aviation accidents and incidents (Shappell & Wiegmann, 1996). To date, however, the causal role of aircrew errors has received the bulk of the attention by both air safety investigators and human factors researchers. Nevertheless, there is a growing concern within the aviation community over safety issues that arise outside the cockpit and an increasing number of aviation safety professionals are being called upon to address these issues. One particular area of growing concern is that of air traffic control.

During the early years of aviation, aircrew avoided becoming lost by using simple cockpit instruments and visual landmarks on the ground. However, both military and commercial demands gradually required pilots to fly in poor visibility conditions and at night. The job of air traffic control was subsequently established to help maintain safe separation between aircraft and to ensure that pilots would not fly their planes into the ground or other obstacles (Hopkin, 1995). Still, as the number of aircraft and demands on air-traffic control services has increased over the decades, so to has the number of accidents, incidents, and runway incursions (loss of safe separation among aircraft and other ground vehicles). As with most aviation accidents today, many of these occurrences have not been due to faulty control equipment, but rather to human error, including mistakes made by air traffic controllers (FAA, 2000).

To date, few attempts have been made to systematically examine ATC-related accidents and incidents to determine the conditions under which these events occur. For example, such factors as the type of aircraft operation (e.g., general aviation vs. commercial), time of day (day vs. night), and meteorological conditions (VMC vs. IMC) have all been shown to influence aviation accidents when examined from a flight deck perspective. These factors may therefore likely affect ATC-related accidents as well. However, unlike the flight deck, ATC personnel and responsibilities are diverse and can include a variety of operators including ground, local, approach/departure (A/D), and air route traffic control center (ARTCC) controllers, as well as tower supervisors and FAA management personnel. The extent to which these personnel are involved in accidents and incidents, and the effects that different

operational factors have on controller performance have received limited attention.

Understanding the types of errors ATC personnel make is also important for identifying possible solutions for preventing or mitigating operator errors. Unfortunately, most accident and incident reporting systems are not designed around any theoretical framework of human error, making the identification of error causes and the development of interventions strategies extremely difficult. To remedy this situation, Shappell & Wiegmann (2000) recently developed the Human Factors Analysis and Classification System (HFACS) that can be used to re-classify and analyze human error data associated with accidents based on the theoretical causes underlying human failure.

The HFACS framework is based on Reason's (1990) model of latent and active failures. Briefly, HFACS encompasses multiple aspects of human error including (1) *Unsafe Acts* (decision errors, skill-based errors, perceptual errors and violations), (2) *Preconditions of Unsafe Acts* (adverse mental states, adverse physiological states, physical mental limitations, CRM failures, and personal readiness), (3) *Supervisory Failures* (inadequate supervision, scheduled inappropriate operations, failure to correct known problems, and supervisory violations) and (4) *Organizational Influences* (resource management, organizational climate, and organizational process).

Several studies using HFACS to examine aircrew errors associated with military, commercial, and general aviation accidents have shown that HFACS can be successfully imposed onto otherwise nebulous databases, allowing unforeseen trends in the types of errors associated with these events to be revealed (Shappell & Wiegmann, 2000). In addition, the application of HFACS to the analysis of ATC operational error reports from the FAA's internal reporting system (Pounds et al., 2000), suggests that HFACS is a viable tool for analyzing human error within the ATC domain, including perhaps, controller errors associated with aviation accidents and incidents.

The purpose of the present study was to further examine ATC-related accidents and incidents over a 13-year period to determined the operational conditions under which such events occur and the frequency with which different control personnel are involved. The HFACS framework was also used as a theoretical framework for identifying and describing trends in the types of controller errors associated with these ATC-related accidents and incidents.

METHODS

A comprehensive review of all U.S. civil aviation accidents and incidents that occurred by between January 1985 and December 1997 was conducted using database records maintained by the NTSB. Of particular interest to this study, were those accidents and incidents attributable, at least in part, to air traffic controllers, excluding flight service personnel. Consequently, accidents due solely to catastrophic failure, maintenance error and unavoidable weather conditions such as turbulence and wind shear were not included. Furthermore, only those accidents in which the investigation was completed, and the cause of the accident determined, were included in this analysis. A total of 110 accidents and 69 incidents met these criteria for inclusion in this study.

RESULTS

Type of Aircraft Operation. Of the 179 ATC-related accidents and incidents, 109 (61%) involved aircraft operating under FAR Part 91 flight rules (i.e., general aviation), and approximately 33% (n = 69) involved aircraft operating under FAR Part 121 scheduled carrier operations. Roughly, 22% (n = 39) of the ATC-related accidents and incidents involved aircraft operating under other fight rules (e.g., FAR Part 135 scheduled operations, military, and public use). However, ATC-related accidents and incidents were not equally distributed across the different types of aircraft operations. Specifically, a larger percentage of ATC-related accidents (81%, n = 89) were associated GA operations than were ATC-related incidents (29%, n = 20), χ^2 (1, N = 179) = 48.00, $p < .001$. In contrast, a larger percentage of ATC-related incidents were associated with FAR part 121 scheduled carrier aircraft (65%, n = 45) than were ATC-related accidents (13%, n = 14), χ^2 (1, N = 179) = 52.87, $p < .001$. No differences were observed between accidents and incidents across the other types of aircraft operations.

Aircraft Location. The majority of ATC-related accidents and incidents (62%, n = 111) involved one or more aircraft that were in the air. A total of 32% (n = 58) involved one or more aircraft that were on the ground, and roughly 6% (n = 10) involved one aircraft on the ground and the other in the air (e.g., in the process of landing). Again however, ATC-related accidents and incidents were not equally distributed across aircraft location, χ^2 (2, N = 179) = 33.21, $p < .001$. Specifically, a larger percentage of ATC-related accidents occurred when aircraft were on the ground (48%, n = 53) than ATC-related incidents (7.2%, n = 5). In contrast, a larger percentage of ATC-related incidents occurred when aircraft were in the air (87%, n = 60) than did ATC-related accidents (46.4%, n =

51). An equally small percentage of ATC-related accidents (5.5%, n = 6) and incidents (5.8%, n = 4) involved air-to-ground events.

Event Components. A total of 111 (61%) of the 179 ATC-related accidents and incidents involved two airplanes colliding or coming in close proximately to each other. The remaining 38% (n = 68) involved aircraft colliding or nearly crashing into other objects or terrain. However, a larger portion of the accidents involved aircraft-object events than did ATC-related incidents, χ^2 (1, N = 179) = 29.66, p < .001. Approximately 54% (n = 59) of all ATC-related accidents involved aircraft colliding with objects and terrain, while only 13% (n = 9) of the ATC-related incidents involved an aircraft-object event.

Meteorological Conditions. The majority of ATC-related accidents and incidents (71%, n = 127) occurred during visual meteorological conditions (VMC). The remaining accidents and incidents occurred during instrument meteorological conditions (IMC). However, a larger percentage of accidents (36%, n = 40) occurred during IMC than did incidents (17%, n = 12), χ^2 (1, N = 179) = 7.41, p < .01.

Time of Day. Approximately 65% (n = 116) of the ATC-related accidents and incidents occurred during daytime hours. The remaining 35% (n = 63) occurred to during non-daylight hours (i.e., dawn/dusk or at night). However, a larger percentage of ATC-related accidents occurred during non-daylight conditions (42.%, n = 46) than did ATC-related incidents (25%, n = 17), χ^2 (1, N = 179) = 5.49, p < .05.

ATC Personnel. The largest percentage of accidents and incidents cited local controllers (41%, n = 74) as contributing to the event, followed by D/A (36%, n = 64), ARTCC (17%, n = 30), tower supervisors (10%, n = 10), ground controllers, (9%, n = 16) and FAA personnel (7%, n = 13). However, a larger percentage of ATC-related accidents were associated with errors committed by ground controllers (14%, n = 15) than ATC-related incidents (1.4%, n = 1), χ^2 (1, N = 179) = 7.74, p < .01. In contrast, a larger percentage of ATC-related incidents were associated with ARTCC errors (25%, n = 17) than ATC-related accidents (12%, n = 13), χ^2 (1, N = 179) = 5.0, p < .05. An equal percentage of ATC-related accidents and incidents were associated with errors committed by local controllers, D/A, tower supervisors, and FAA personnel.

ATC Error Classification. Within the *Unsafe Acts* level of the HFACS framework, skill-based errors by ATC personnel were associated with the largest percentage of accidents and incidents (82%, n = 147), followed by violations (33%, n = 59), decision errors (2.2%, n = 4) and perceptual errors (1.1%, n = 2). However, a larger percentage of ATC-related accidents were associated with skill-based errors (90%, n = 99) than incidents (70%, n = 48), χ^2 (1, N = 179) = 12.06, p < .001. A larger percentage of incidents involved violations (48%, n = 33) than accidents (24%, n = 26), χ^2 (1, N = 179) = 11.23, p < .001. Within the *Preconditions of Unsafe Acts* level, only CRM was cited in more than 10% of the events (17%, n = 30), with a slightly larger percentage of incidents involving CRM failures (23.2%, n = 16) than accidents (13%, n = 14), χ^2 (1, N = 179) = 3.33, p = .068. Within the *Unsafe Supervisory* level, only inadequate supervision was cited in more than two reports (n = 25, 14%), and within the *Organizational Influences* level, only operational process was cited in greater than three reports (n = 15, 8%). There were no differences in the percentage of ATC-related accidents and incidents associated with supervisory or organizational factors.

DISCUSSION

In general, ATC-related accidents and incidents are infrequent events. Given that over 2,000 civil aviation accidents occur annually in the U.S. (NTSB, 2001), the relatively small number of ATC-related events is promising. Still, the data reported here indicated that when ATC-related accidents and incidents do happen, they are likely to involve local controllers interacting with two aircraft, in the air, during daylight, VMC conditions. Consequently, these findings suggest that ATC-related events, in general, are not due to any visual restrictions placed on either the controller or flight crew but rather to some other error-inducing factors. Indeed, the HFACS analysis performed on the error data indicated that the most common type of ATC error was skill-based, indicating a breakdown in attentional or memory processes of controllers.

Some notable differences, however, were observed between ATC-related accidents and incidents. For example, ATC-related accidents were more likely to involve skill-based errors of ground controllers while dealing with GA aircraft on the ground during nighttime or IMC conditions, which ultimately resulted in the aircraft colliding with another object other than an airplane. In contrast, ATC-related incidents were more likely to involve ARTCC controllers failing to follow rules and procedures while interacting with FAR Part 121 aircraft in the air during daylight, VFR conditions, resulting in near mid-air collisions.

These finding suggest that ATC-related accidents and incidents are not just different ends of the same continuum (i.e., that incidents are only a heartbeat away from an accident). Indeed, several studies have shown that pilot-related accidents and incidents also

differ in the types of information processing errors made by pilots (Wiegmann & Shappell, 1997). Perhaps ATC-related incidents do not turn into accidents, because they generally occur in a more forgiving or error-tolerant environment. For example, FAR Part 121 aircraft are always operated by two highly skilled pilots that share see-and-avoid responsibilities. This starkly contrasts to GA aviation that in many instances involves a single, low-time pilot. Therefore, it is not surprising that the GA pilot who encounters an ATC error on the ground during nighttime or IMC conditions is more likely to have an accident than pilots operating aircraft under FAR Part 121 rules who encounter an ATC error in the air, during VMC conditions that allows for better conflict detection and maneuvering of the aircraft.

It should be noted that relatively few of the ATC-related accidents and incidents cited supervisory or organizational factors as contributing to the unsafe acts committed by ATC personnel. This finding is similar to the results of a previous study of commercial aviation accidents associated with aircrew errors (Wiegmann & Shappell, in press). One explanation for the relative scarcity of such factors could be that contrary to Reason's (1990) model of latent and active failures upon which the HFACS framework is based, such supervisory and organizational factors simply do not play as large of a role in the etiology of ATC-related accidents and incidents as once expected. Another, equally plausible explanation, is that these factors do contribute to most accidents, yet they are rarely identified using existing accident investigation processes.

Previous HFACS analyses of ATC operational error reports from the FAA's internal reporting system support the latter interpretation of the present data (Pounds et al., 2000). That is, that supervisory and organizational factors do play a role in affecting unsafe acts committed by controllers. Furthermore, the present finding that nearly 1/3 of all ATC-related accidents and incidents involved violations by default implicates the presence of other organizational or systemic factors that tolerate or possibly even reinforce such actions (Reason, 1990). Clearly, if the underlying causes of ATC-related accidents and incidents are to be effectively addressed, more thorough investigative systems need to be developed that help identify both latent and active failures associated with these events.

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