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ANALYSIS OF MID-AIR COLLISIONS IN CIVIL AVIATION

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Mid Air Collisions (MAC) are tragic events, with the potential of multiple fatalities. Despite the improving trends in aviation safety, the rate of MAC has remained stable for the past few years. There is an absence of published literature on MAC and related human performance issues. Consequently, this study analyzed 79 mid air collisions in civil aviation in the United States from 1994 to 1999 in an attempt to further understand the causes of these accidents. Contextual data was analyzed in terms of accident location, phase of flight, type of aircraft operation, visibility conditions, and direction of aircraft trajectories (same vs. opposite direction). Pilot factors were also examined, including recent flying experience and medical certification. An attempt is made to interpret the results in terms of recent models of pilot vigilance and scan patterns. Recommendations are made for possible future research in the area.

INTRODUCTION

A Mid Air Collision (MAC) is a tragic event, involving at least two pilots as well as possible occupants of the aircraft with the potential of multiple fatalities. Despite the improving trends in aviation safety, the rate of MAC has remained stable at 0.035 /100000 flying hours for the past several years (FAA, 1998) and still remains a cause for concern. No MACs involving an air carrier aircraft have occurred in over a decade, but with an increasing number of aircraft in the air, the possibility of such an accident occurring still exists.

Constant vigilance to achieve collision avoidance remains the basic responsibility and tenets of flying in Visual Flying Rules (VFR) conditions. This vigilance is not just limited to the time spent looking outside, but includes a basic understanding of the limitations of vision and developing efficient scan patterns. Furthermore, there is an absence of published literature on MAC, as well as the basic scan patterns of pilots during various phases of flying. Consequently, this study was carried out to analyze aspects of aircraft accidents involving MAC from 1994-99 to identify possible human factors causes.

MATERIAL AND METHODS

Data was retrieved from the NTSB web site for all accidents from 01/01/1994 to 12/31/1999. Of particular interest were those accidents classified as "Mid air Collision." Only accident reports that had been finalized and had a cause of accident endorsed by the NTSB investigators were included in the study. Seventy-nine MAC fulfilled the criteria.

RESULTS AND DISCUSSION

Aircraft Operation

Cessna aircraft accounted for 41% of the aircraft, followed by Piper and Beech. A total of 93% of the aircraft involved in mid air collisions were operating under CFR 91 (general aviation under VFR) and were being flown for personal use (n=75). No matter how good the visibility from the cockpit, all aircraft have blind spots. The major difference among various makes and models is the wing position. High-wing aircraft have reduced visibility of aircraft above them; low- wing aircraft have a large blind spot beneath them that may obscure conflicting traffic when descending into the pattern. However, few of the accident reports cited restricted visibility between a low–high wing configuration aircraft as a possible contributing factor.

Location and Phase of Flight

A large number of MACs occurred when aircraft were in the approach phase (n=61, 38.6%) followed by cruise (n=42, 26.6%) and maneuver (n=27, 17.1%). There are two plausible explanations for the large number of accidents occurring during the approach phase. Firstly, approach and landing is considered a stressful portion demanding aviation skills of the highest order to process information both from the instrument panel as well as the outside world, besides communicating with the air traffic control. Secondly, given the small funnel of airspace planes occupy during the landing, any confusion about who's landing in what order, and where they are, can often lead to MACs.

MAC occurring during cruise are surprising, because without the distractions created by arrival and departure, cruise is the phase of flight when pilots have the most time to look for traffic. But, it is the also the longest phase of flight and the time for greatest complacency. According to the NTSB, one common thread links the majority of these accidents: inattention on the part of the crews of both aircraft (Air Safety Foundation, 2001). MAC while maneuvering in the traffic pattern may occur as a result of improper or misunderstood position reports, or erroneous assumptions. This is particularly true at non-towered airports.

Although 73% of the MAC occurred away from the airport, it was seen that majority of them were within 3 miles from the airport. Most of the approach accidents occurred on non-towered airports. Information from the narrative revealed that all MAC occurred below 6000 feet, with 50% below 1000 feet altitude. The FAA also specifies that traffic tends to congest around regulatory airspace borders, or around the airports where GA aircraft flying under VFR tend to circumnavigate, awaiting clearance to enter (FAA, 1989).

Direction of Travel

Information from the narrative was used to classify MAC based on the direction of travel at the time of accident. Approximately, 35.4% of the MAC involved aircraft traveling in opposite (head on) direction, whereas the rest of them involved aircraft traveling generally in converging directions. Many such accidents result from a faster aircraft overtaking and hitting a slower moving airplane.

Visibility Conditions

Meteorological conditions had almost no role to play, with all the MAC occurring under VMC conditions; all but 4 MAC occurred with visibility more than 5 miles. Majority of the MAC occurred during the daylight hours. These findings reconfirm the recommendations of the FAA on the subject that extra vigilance should be adopted when flying in good weather with miles of visibility (FAA, 2001). Zeller mentions that 80% of the MAC in the Air Force occurred in daylight, good weather VFR conditions (Zeller, 1959). Atmospheric conditions in the form of haze and sun glare were mentioned in 12 cases, both of which can affect target visibility.

Accident Severity

Almost 50% of the aircraft were destroyed, maximum damage occurring when they were in the cruise phase. Similarly, 45% of the MAC involved fatalities and there were increased fatalities among pilots (67%) during the cruise phase of flight. The lowest percentage of fatalities occurred in MACs occurring during the approach/landing phase. This appears to be a function of aircraft speed (cruise speed > approach/landing speed) and the altitude (cruise altitude > approach/landing altitude).

Pilot Information

The majority of the pilots involved were holding a PPL/CPL license and a Class II/III medical certificate. However, half of pilots had certificates with an endorsement of a medical waiver, the details of which were not available. Data on the age of the pilots was also not available in the NTSB reports.

There were two peaks in terms of experience. Approximately, 38% of the pilots had less than 1000 hours of total flying experience, whereas 25% had more than 5000 hours. Flying experience on type parallels this finding. These findings suggest that MACs may not be simply due to either a lack of skill/experience or the onset of complacency due to seasoned experience.

Indeed, the majority of the pilots had not flown in the last 24 hours (n=83, 52.5%) and even in the 30 days (n=60, 38%) preceding the MAC. This finding raises the question of how much flying is good enough to maintain proficiency? In the military, it is customary for a pilot to undergo a check ride/refresher flying after a period of lay off (say one month leave/absence from flying). The basis being that certain skilled activities do need to be refreshed, despite prior experience, after a period of non-engagement.

NTSB Cause Factors

Why then do MACs occur in conditions so ideal for flying? The answer to this question is obvious both to a layman as well as the learned investigator: *inadequate look out by the pilot/pilots*. A total of 85% (n= 67) MAC accidents involved inadequate lookout by one pilot as a cause.

The NTSB in its report on the 1956 MAC over the Grand Canyon probably sums up this finding for almost all the MAC: “the pilots did not see each other in time to avoid collision. Evidence suggest that it resulted from any one or a combination of the following factors: intervening clouds, visual limitations due to cockpit visibility, preoccupation with normal cockpit duties, preoccupation with matters unrelated to cockpit duties …(and) physiological limits to human vision reducing the time and opportunity to see and avoid the other aircraft”(Air Safety Foundation, 2001).

GENERAL DISCUSSION

The rules for maintaining separation from other aircraft in VFR conditions are spelled out in FAR 91.113: “when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft” (Air Safety Foundation, 2001). “See and avoid “ is the common terminology for this method of collision avoidance.

Vision is the most important tool pilots have to “see and avoid” other aircraft. The key factors though are the total time and the nature of scans the pilot uses in scanning the outside world looking for other aircraft. The FAA in their aeronautical information manual advice airmen about the measures that help in avoiding mid air collisions, besides others, which would help them in safe flights (FAA, 2001). It is suggested that the time a pilot spends on visual tasks inside the cabin should represent no more that $^1/_4$ to $^1/_3$ of the scan time outside, or no more than 4 to 5 seconds on the instrument panel for every 16 seconds outside. Since the brain is already trained to process sight information that is presented from left to right, one may find it easier to start scanning over the left shoulder and proceed across the windshield to the right.

Wickens, Xu, Helleberg, Carbonari, and Marsh (2000) discussed several interesting features about pilot scanning behaviors/patterns, which could largely explain the findings of this study. Using eye tracking devices to track pilots eye movements while flying a simulator with real-world cockpit views, they found that the pilots spent approximately 37% of their time attending to the outside world, a value that contrasts sharply with the FAA recommended figure of approximately 75%. The results also indicate that the dwells (time spent on an area of interest) were significantly longer on the Instrument panel (6.6 sec with a maximum of 18 sec) than on the outside world (OW) (2.9 sec). This finding could explain to a large extent the implication of ‘inadequate’ in the causation of MAC and calls for further research on the basic scan pattern requirements to avoid MAC.

Wickens et al. (2000) have also proposed a model of change detection. They propose that four determinants influence change detection (target detection on appearance in the field of view). Firstly, the *salience* of the target. The next factor influencing target detection is the *expectancy* of finding a target, implying that a cue given by some means about the target would enable detection earlier then otherwise. Thirdly, the probability of detecting a target would be the *value* placed on detection. If a pilot were himself responsible for detection and avoiding traffic, more value would be assigned to this task compared to the situation when the pilot is totally under the ATC. The fourth factor is the *effort or workload* of maneuvering involved in detection and avoidance.

Applying this model to the MAC data may help further explain the findings. During cruise, when general aviation pilots are not under the control of ATC, they are in unregulated airspace at low altitude with many other similar aircraft (hence the target *expectancy* and detection *value* should be higher). In turn, the *workload* cost should be low, because during cruise the outside world provides a lot of information with regards to navigation. Yet, MACs have occurred in a large number during this phase. Therefore, according to the model, MACs during cruise are likely to be due to the issue of *saliency*. The eyes during cruise accommodate at a finite distance (a known fact) in the absence of visual cues and it may require a deliberate attempt to re-accommodate the eyes in an attempt to look for far off targets, and hence the delayed reaction in detection.

Another large portion of MAC accidents occurred during the approach and landing phases of flight. Based on the above model, it would seem reasonable to assume that pilots would be more vigilant to detect aircraft near the vicinity of an airport, both because of the likelihood (*expectancy*) of encountering one and the increased incidence of a MAC near an airport. The *saliency* of other aircraft would also be high, due to the closeness within the airspace. *Value* may also be high, if the airport does not have an ATC tower. However, these factors may be counteracted by the high *workload* during approach and landing, wherein scanning of instruments to maintain various critical flight parameters, as well as communicating intentions to other aircraft in the area is required. Currency in flying will influence the amount of workload a pilot perceives, age and any medical fitness will also play a part. Indeed, the majority of the MACs involved pilots that had very little recent flight time prior to the accident.

The other factor in detection and perception of targets is that of prior experience of similar situations. It is postulated that a pilot once having gone through the images of a near mid air collision approaching from distance, would have a mental representation of what a target on collision course looks like, thus making detection much easier and faster. This issue also relates to the concept of '*priming*'**,** which refers to a change in the ability to identify an item as a consequence of a specific prior encounter (Schacter & Badgaiyan, 2001). If this hypothesis is validated by future studies, it could have far reaching implications in reducing MACs by being incorporated in flying training syllabi.

RECOMMENDATIONS

There is a need to develop a model of adequate lookout for the pilot. This should include documenting and studying scan patterns of pilots, the time spent inside/and outside the cockpit under all phases of flight and how they compare with current FAA recommendations on the subject.

It may be interesting to study the effect of exposure of the pilots to a simulated near mid air collision on a simulator/PC device. If research validates the hypothesis that a simulated experience of near mid air collision can lead to an early detection of targets, it could have far reaching training implications.

Age and experience needs to be tested on all these issues so that realistic data could be generated. A good starting point would be the analysis of pilot in command characteristics in terms of age, experience and medical waivers and MAC.

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