Characteristics of U.S. Midairs

by Robert C. Matthews, Ph.D.

On August 9, 2000, a Piper PA-31 *Chieftain* and a PA-44 *Seminole* collided in midair in Burlington County in southern New Jersey. The PA-31 was operating as an unscheduled Part 135 flight under contract with the U.S. Navy and had nine persons on board. The PA-44 was operating as an instructional flight and had a student and an instructor on board. All 11 people were killed. Both aircraft were destroyed. An unoccupied home also was destroyed.

The collision quickly led the FAA's Office of Accident Investigation to review all 329 midair collisions involving U.S. registered aircraft from 1983 through the date of this accident. The review confirmed some well-understood characteristics of midairs and found some characteristics that had not been identified in the past.

GENERAL CHARACTERISTICS OF MIDAIRS

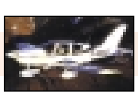
Midair collisions in the U.S. had decreased steadily for over 30 years, but the number has stabilized since 1995 at about 16 per year. From 1983 through August 2000, the U.S. had a total of 329 midair collisions involving 658 aircraft. The 658 aircraft included 14 balloons; 25 gliders; and nine military aircraft, four of which were helicopters.

For the past two decades, midair collisions in U.S. airspace have almost exclusively involved general aviation (GA) aircraft. Midairs involving large commercial aircraft have been virtually eliminated in U.S. airspace.

Since 1995, GA has averaged one midair collision per 1.6 million flight hours. Given that a midair involves two aircraft, this yields an average risk of a midair today of about one per 800,000 flight hours. For instructional and recreational flight, the risk approaches one per 400,000 flight hours. In short, any single pilot's chance of a midair is small, but it is not insignificant.

Yet "only" 56 percent of the 329 midairs involved fatalities and "only" 40 percent of the 658 aircraft had fatalities. This was somewhat surprising: 60 percent of all aircraft involved in midairs manage to land safely, while both aircraft manage to land safely in 44 percent of all midairs. In short, midairs are not always catastrophic.

The aviation community has long understood that poor weather is not a factor in midairs. All 329 midairs from 1983 through August 200 occurred in visual meteorological conditions (VMC). Perhaps the only surprise related to weather was the utter ab-



sence of any exceptions to the rule of VMC. Bright sun was the only commonly cited factor related to weather. Similarly, darkness does not explain midairs. Only six of the 329 midairs occurred at night and just four occurred at dusk.

The review also found that "inadequate visual lookout - failure to see and avoid," remains the most common causal factor identified by the National Transportation Safety Board (NTSB). Accident reports from the NTSB indicate that about 88 percent of pilots involved in midairs never see the other aircraft in time to initiate evasive maneuvers; only 12 percent of the 658 pilots appear to have begun reacting to an impending collision. The second most common factor, though a distant second, was pilot failure to follow procedures. These procedures most commonly include inappropriate entry into landing patterns and failure to use the UNICOM radio frequency at nontowered airports.

However, the failure to see and avoid other aircraft is not strongly correlated to closing speeds. In fact, most midairs involve relatively low closing speeds, as one aircraft usually strikes the other aircraft from the rear, from above, or from a quartering angle.

Traffic density is a major factor in midairs. The typical midair occurs at low altitude on approach and landing or, somewhat less frequently, on takeoff and climbout. In short, most midairs occur near airports, especially nontowered airports. This has been understood for years and it makes intuitive sense. Any highway traffic engineer can tell us that the risk of a multi-vehicle collision increases as traffic density increases. Surprise: multi-vehicle accidents tend to occur where we find concentrations of vehicles operating in a fixed space.

Conversely, midairs at high altitude are rare events. Most of those that do occur at high altitude involve formation flying. Formation flights account for 14 percent of all midairs. These include professional performances and practices and well-prepared amateurs, but ill-prepared amateurs are badly overrepresented. In short, be prepared if you plan to fly along side a friend or family member. Agree upon clearly stated communication procedures and clearly stated flight paths relative to each other, and allow for major differences in aircraft performance.

This notion of traffic concentration helps to explain why student pilots are involved in a disproportionate share of midairs: student pilots are involved in 36.5 percent of midairs and account for 22.5 percent of pilots involved in midairs. This arithmetic indicates that about 7.25 percent of all midairs involve students in both aircraft. The high frequency of students may reflect their relative lack of experience. However, it also reflects traffic density, as students tend to fly to and from nontowered airports, with frequent takeoffs and landings and frequent entry into traffic patterns. These are the phases of flight in which traffic density is high. The high share of student flights also may suggest that, at least in those flights that result in midairs, instructional pilots may be distracted with instruction and not properly monitoring the flight.

Yet, despite the high percentage of instructional flights, the data indicates that experience is not a very effective insurance policy against midairs. Half the pilots involved in midairs since 1983 had more than 1,500 hours total flight time, while one-third of the pilots had more than 3,000 hours.

INHERENT LIMITATIONS OF SEE AND AVOID

The 329 midair collisions indicate that see-and-avoid has inherent limitations as a tactic or strategy for avoiding midair collisions. This is certainly true of midair collisions that involve high closing speeds, but it is also true of midairs that involve low closing speeds.

The human eye can detect and recognize an aircraft the size of a PA-31 or a comparable Cessna at a maximum of 1.5 miles. If the closing angle is head-on, or nearly so, even two small and relatively slow civil aircraft close at speeds in excess of 200 knots. This allows a maximum of 25 seconds for evasion under ideal conditions. However, the ideal is reduced by various factors, including the following.

- First, substantial time is required to scan the horizon properly. The human eye requires small changes in the radial being scanned, plus time to focus on each new scan. To scan just 130 degrees of the horizon and focus on interim target areas, a pilot requires up to 20 seconds. A target aircraft may not be visible when the pilot scans and focuses on a radial and, by the time the pilot returns to that radial, closing time may be prohibitively short.
- Ideal conditions also are reduced when a pilot's attention is focused inside the cockpit, where workload reduces the time a pilot spends scanning. Workload is highest during approach/landing and takeoff/climb-out, when most midairs occur.
- See-and-avoid also is limited by the absence of visual contrast between a target aircraft in a clear or hazy sky, which substantially shortens the 1.5 miles. This is especially true when either pilot is flying toward the sun. In addition, high-wing aircraft restrict a pilot's ability to scan above his or her altitude, while low-wing aircraft restrict the ability to scan below the aircraft.

Any of the factors identified above can reduce the effectiveness of see-and-avoid. The combination of any two or more factors can reduce the practical time available for a safe, evasive maneuver to just a few seconds or less. This is true even where closing speeds are relatively slow due to closing from the rear, from above, or from quartering angles.

Does all this mean that see-and-avoid is useless or that it should be abandoned? Hardly! Though we know a lot about the characteristics of midair collisions, the fact is that we know relatively little about the role of see-and-avoid or other factors when

collisions are narrowly avoided between two GA aircraft. No aviation safety agency in the world could, with a straight face, advise pilots to forget about visual scanning. In short, the point here is not that visual scanning and see-and-avoid lack any merit. Rather, see-and-avoid has real merit, but, as a primary strategy for further reductions in midairs, its limitations are equally real.

In the end, however, the number of midairs in the U.S. has decreased significantly and steadily for at least 35 years, even as traffic has increased. The improvement, especially when measured per 100,000 flight hours, has been too persistent and too substantial to be the product of mere chance, as indicated in Table One. Something really has changed for the better. Factors include improved air traffic control services and coverage, changes in airspace structure, and the introduction of transponders.

In the airline world, midairs in U.S. airspace appear to have virtually disappeared. Fatal midairs in large commercial aircraft (over 30 seats) were a fairly common event for more than 30 years (1946-1978) with a steady average of about one fatal airline midair per year. However, following the 1978 midair collision in San Diego, the once common accident scenario has disappeared. The principal factors explaining this rather sudden and dramatic change include: on-board Traffic Collision Avoidance System (TCAS), corresponding ATC equipment, and the requirement to be equipped with Mode C in airspace around the nation's busiest commercial airports.

CONCLUSIONS

The bottom line, of course, is how a typical GA pilot can hope to reduce his or her risk of midair even further. The temptation is to recommend an expensive technological fix that is comparable to the current version of TCAS now used by the airlines. In fact, the best hope for a pilot to reduce his or her risk of a midair collision rests with strategies that are less sexy and not so very new.

For example, the data suggests that disciplined adherence to procedures (proper entry into landing patterns, proper departure patterns) and proper use of the UNICOM frequency at uncontrolled airports could go a long way towards reducing the number of midairs. Similarly, operating into and from towered airports, when possible, could reduce risk. Flight instructors can reduce their risk by forcing themselves to remain cognizant of other aircraft, or even by choosing to conduct some initial training at airports and in airspace that have very little traffic. Yet, old fashioned scanning (see-and-avoid) remains the primary strategy. The catch is that, as a basic tool for avoiding midair collisions, see-and-avoid has its limits and requires other strategies or tactics if a pilot is to reduce his or her risk.

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Table 1. MIDAIR COLLISIONS 1983-1999
*(*2000 accident totals are preliminary for the entire year. The 2000 numbers used in this article were only until August, so the totals will not match the numbers used in the article.)*

Year	Midair Collisions	Fatal Midairs	Aircraft Involved	Aircraft with Fatalities	Onboard Fatalities	Total Onboard
1983	14	8	28	12	20	54
1984	25	14	50	22	45	93
1985	25	14	50	18	32	115
1986	29	17	58	24	121	178
1987	25	13	50	22	39	108
1988	19	9	38	11	15	58
1989	18	12	36	21	38	63
1990	21	12	42	18	24	82
1991	23	13	46	18	34	88
1992	13	7	26	10	26	74
1993	13	7	26	13	20	114
1994	12	8	24	12	19	38
1995	15	8	30	13	21	48
1996	19	6	38	10	17	75
1997	15	11	30	17	26	61
1998	15	12	30	20	24	48
1999	17	8	34	13	17	51
2000*	10	11	38	18	32	65
Total	**337**	**190**	**674**	**292**	**570**	**1,413**