# Measuring Safety in Single- and Twin-engine Helicopters

*Accurate measurement of helicopter safety is crucial to both the flying public and the operators of rotary-wing aircraft. The author questions the veracity of some safety statistics and he challenges recent ICAO amendments that would restrict operations in single-engine helicopters in favor of twin-engine helicopters.*

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Safety has always been a paramount concern in aviation. Safety is not an absolute; rather it is a relative measure of the risk involved when flying in an aircraft. Several methods are used to measure safety, but some can be misleading and create a perception of a low level of safety in helicopters. Misconceptions about helicopter safety can cause overly restrictive regulations and prohibit the use of safe aircraft. Thus, realistic measurement of helicopter safety is crucial to helicopter operators and the flying public.

There is a question of whether an occupant is safer in a single-engine or a twin-engine helicopter. Some say that two engines have to be better than one, arguing that since there are so many twin-engine aircraft used in commercial fixed-wing operations, therefore, helicopters also need two engines. However, the facts do not support applying fixed-wing thinking to helicopters. Helicopters are unique and they are operated in difficult environments; therefore, they should be considered differently from fixed-wing airplanes. One must consider all causes of accidents and injuries, not just mechanical components such as engines or tail rotor blades.

Accident data from the United States (U.S.), the United Kingdom (U.K.), and Canada were analyzed to determine the risk to occupants of single- and twin-engine helicopters. These three nations account for about 82 percent of all known non-Soviet bloc civil helicopters.

## Why Measure Safety?

Many important equipment decisions made by businesses, government agencies and individuals are based on the perceived safety of an aircraft. Decisions to buy, use, repair, improve, insure, and sell or replace an aircraft are related to perceived safety. Likewise, government operational prohibitions are based on a perceived deterioration of safety. For example, recent Amendment 1 to ICAO (International Civil Aviation Organization) Annex 6, Part III[1] establishes three helicopter performance categories and recommends certain operational limitations. The categories are:

- Performance Class 1 includes multi-engine helicopters that are capable of continuing normal operations with one engine inoperative regardless of when the engine fails.

- Performance Class 2 includes multi-engine helicopters that are capable of continuing flight after one engine fails except that a forced landing would be required following an engine failure between takeoff and a specified point and from a specified point to landing.

- Performance Class 3 refers to single-engine helicopter operations; a forced landing is required after engine failure.

The ICAO amendment would encourage the prohibition in member countries (states) against the use of Performance Class 3 (single-engine) helicopters for IFR (instrument flight rules) flights, night flying, flights out of sight of land, flights with cloud ceilings of lower than 600 feet or visibility less than 1,500 meters, and flights to elevated structures (heliports). *[ICAO does not regulate; it recommends that individual states adopt its criteria into their own regulations. The United States and many other countries have not adopted the recommendations of ICAO Amendment 1 to Annex 6 Part III. — Ed.]*

Because single-engine helicopters account for three out of four helicopters in the world, this action will have a drastic effect upon the helicopter community and upon the public benefit derived from helicopter use. Some single-engine helicopter operations will no longer be performed because of the higher costs involved if twin-engine helicopters are mandated. Most multi-engine helicopter operations are conducted in Performance Class 2. Because the accident data do not discriminate between performance classes, the safety comparisons of Performance Classes 2 and 3 from the available data are accomplished in this discussion by looking at the differences between single-engine (Performance Class 3) and multi-engine (Performance Class 2 ) operations.

The performance class restrictions on helicopter operations in accordance with the ICAO Amendment 1 change includes the recommended prohibition of single-engine helicopter operations involving transport of passengers, cargo or mail for remuneration or hire. This prohibition is based upon a perceived belief that twin-engine helicopters are always safer than single-engine helicopters in all environments. Accurate helicopter safety measurements are critical for perceived safety and actual safety to be accurately differentiated. Such accuracy also allows prioritized correction of safety problems and the evaluation of desirable and undesirable aspects of different aircraft configurations. Of personal importance to an individual, this can allow a person to determine his risk of flying in a specific type aircraft.

## Why Worry About Safety?

Why do people worry about safety in the first place? The primary reason is that no one wants to suffer injury or death. Because we do not want to think about our own injury or death, many of us tell ourselves, "I am not ever going to be in an accident, therefore I won't have to worry about being injured or killed." Aviation accident prevention is based on this concept: "If I can prevent the emergency, I won't have to worry about my pain and my death." This human coping mechanism works well for the average individual; but management (aviation and regulatory) must first determine the actual risk and subsequently manage the risk. Safety is the management of risk.

## Helicopters Respond Differently To A Power Loss Than Do Airplanes

If an engine power loss occurs, the resulting emergency landings are significantly different for airplanes as compared to helicopters. To maintain control of an airplane, its airspeed must stay above the stalling speed of the wing until ground contact. This means that the airplane's airspeed at ground contact will be typically 60 to 100 knots. This high speed requires a shallow approach angle and a long, cleared landing site. Any obstructions (trees, buildings, fences or ground irregularities) can be impacted by an aircraft with significant crash forces and cause injuries.

Conversely, helicopters require little more room than the size of the aircraft for an unpowered, emergency landing. This is because the helicopter can descend under control after engine failure in a condition known as autorotation, whereby the pilot decreases the pitch of the main rotor blades to allow them to be rotated by the air flowing upwards through the rotor arc, or disc, similar to the action of wind on a windmill. The spinning main rotor acts somewhat like a parachute and a near-constant descent rate is maintained. The pilot retains full control and is able to select the most appropriate landing site. A few feet above the ground, the pilot flares the aircraft and increases the pitch of the rotor blades, which increases lift. This allows the descent to be slowed just before ground contact to allow a gentle touchdown at little or no forward speed when accomplished properly (Figure 1).

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**Figure 1. Helicopter autorotation**

## Helicopters Have Different Missions And Uses

Using U.S. National Transportation Safety Board (NTSB) accident data for 1982 through 1985 for U.S.-registered helicopters, the mission under way at the time of the accident was determined[2], and is shown in Table 1. This shows that single-piston, single-turbine and twin-turbine helicopters are used in the same missions but in varying degrees. Single-engine, piston-powered helicopters have a concentration in relatively high-risk areas of flight training, personal and agricultural work where low cost is a driving factor. These uses are major contributors to the safety record for single-piston helicopters. If twin-turbine helicopters performed similar missions and were operated as the single-engine, piston-powered helicopters, the twin-turbine helicopter accident rate could rise significantly.

**Table 1. Helicopter Missions at Time of Accident (NTSB Data 1982-1985 percent of accidents)**

| Type of Operations | Single-piston | Single-turbine | Twin-turbine | All Helicopters |
|---|---|---|---|---|
| Personal | 26.2 | 24.4 | 16.0 | 24.9 |
| Business | 9.4 | 23.6 | 32.0 | 14.9 |
| Instruction | 21.3 | 2.0 | 8.0 | 14.4 |
| Executive/Corporate | 0 | 5.6 | 16.0 | 2.4 |
| Agricultural | 29.8 | 8.8 | 4.0 | 21.9 |
| Observation/Survey | 5.1 | 5.2 | 0 | 5.0 |
| Public-use | 1.1 | 4.0 | 8.0 | 2.3 |
| Ferry | 1.9 | 4.4 | 16.0 | 3.2 |
| Positioning | 0.4 | 0.4 | 0 | 0.4 |
| Other Work | 4.8 | 21.6 | 0 | 10.6 |

## Helicopter Fleet Is Mixed

The U.S. Airmen and Aircraft Registry of August 1990 shows the distribution of helicopters (Table 2). There were 34 military surplus twin-piston helicopters on the registry that were not included. However, the number of aircraft on the registry can be misleading because it includes many aircraft that are wrecked, being salvaged for parts, under repair, stored or used as static (nonflying) aircraft. Flight hours are a better indicator of actual aircraft usage.

**Table 2. U.S.-Registered Helicopters by Engine Type (U.S. FAA Data)**

| Type of Engine | Number of Helicopters (11-31-90 Registry) | Flight Hours Flown 1984-1988 | Flight Hours (%) |
|---|---|---|---|
| Single-piston | 5,5371 | 2,961,252 | 25.9 |
| Single-turbine | 3,642 | 7,035,846 | 61.5 |
| Twin-turbine | 1,108 | 1,442,116 | 12.6 |
| Total helicopters | 10,121 | 11,439,214 | 100 |
| Aircraft with most flight hours: Bell Model 206 single-turbine only | 2,092 | 5,215,001 | 45.6 |

Flight hours by model series were extracted from the U.S. Federal Aviation Administration (FAA) General Aviation Activities and Avionics Survey annual reports for 1984 to 1988. If the FAA estimated flight hours for a model for two or more years of the five-year period, those flight hours were used. The accidents of that model series were used if flight hours occurred in the year of the accident. If no hours or one year of flight hours were estimated by the FAA reports, the accidents and flights hours for those affected models were deleted from the study. The data is considered by the author to be the best available and is therefore used in this discussion.

The usable models with their flight hours were then arranged in groups: single-piston, single-turbine, twin-turbine helicopters and the most common helicopter, the Bell Model 206. The Model 206 flew 45 percent of all helicopter flight hours during the 1984 through 1988 time period. The single-turbine engine Model 206 is also included in the generic single-engine data.

The Canadian, U.K. and U.S. helicopter fleet flight-hours shown in Table 3 indicate that these helicopter fleets are also varied. The Canadian accident and flight hour data from the Transportation Safety Board of Canada and Canadian Aviation Statistics Centre were for the period 1982 through 1987. The accident data and flight hours from the U.K. Civil Aviation Authority were for the period 1980 through 1987. The mixture of flying in the U.K. fleet is significantly different than in Canada and the United States. This helps to explain why attitudes about helicopter operations vary among ICAO states. The most common helicopter flying in the U.K. during the period was the Sikorsky S-61 twin turbine which accounted for 28.2 percent of the U.K. flight hours, whereas that for the Model 206 was 12.3 percent.

Disregarding homebuilt and experimental helicopters, it is estimated that of approximately 15,200 rotorcraft in the world (excluding the Soviet bloc states), that 12,511, or 82 percent, are in the United States, the United Kingdom and Canada. The helicopter data are presented by configuration groups of single-piston (SP), single-turbine (ST) and twin-turbine (TT).

**Table 3. U.S., U.K., and Canada Civil Helicopters by Engine Type (flight-hours flown)**

| Engine Type | U.S. (1984-88) | U.K. (1980-87) | Canada (1982-87) | U.S./U.K./ Canada Combined | Percent |
|---|---|---|---|---|---|
| Single-piston | 2,961,252 | 91,737 | 190,894 | 3,243,883 | 21.3 |
| Single-turbine | 7,035,846 | 239,548 | 2,078,376 | 9,353,770 | 61.5 |
| Twin-turbine | 1,442,116 | 932,474 | 242,696 | 2,617,286 | 17.2 |
| Total helicopters | 11,439,214 | 1,263,759 | 2,511,966 | 15,214,939 | 100.0 |
| Bell Model 206 single turbine only | 5,215,001 | 155,648 | 1,471,675 | 8,703,602 | 45.0 |

## The Next Step Is Measuring Safety

Now that we have some indication of the helicopter activities, the next step is to measure safety, or determine relative risk. There are various methods in use. Using the total number of accidents that have occurred for a particular model may be misleading because it does not account for fleet size and subsequent exposure through the years. Accidents per amount of exposure is a more appropriate method to determine relative risk.

## Accidents Per Fleet Ratio Is a Slight Improvement

One means of addressing the effects of fleet size is to determine the ratio of accidents to the size of the fleet in existence at the time of the comparison. For example, this ratio is determined by counting the number of accidents that have occurred involving a specific model since its introduction in the United States. This total accident history number is then divided by the latest "estimated" number of active helicopters of that model in the United States. The ratio technique is inaccurate and misleading; it disregards the changing fleet size over the years by using only the latest year's active fleet; looks at models in different periods of their service life; and disregards the different amount of flying done by various models. Also, the number of accidents will increase as a model fleet is utilized. In Figure 2, the Bell Model 47, which is the oldest civil helicopter model, suggests what may happen to the other models as they mature in the future. The number of accidents from 1958 through 1963 was estimated from accident trends before and after that period. Since the number of "active" helicopters is seldom known, the actual numbers of civil aircraft delivered with a U.S. registry number were used. (The last Model 47 was delivered in 1973 in the United States.)

The total number of accidents grows each year and far exceeds the number of aircraft delivered. Obviously, the ratio of total accidents to the number of aircraft in an existing fleet is going to be different depending upon when that ratio is calculated. If the ratio is determined within two years of model introduction, it will probably be low. Five, 10 or 15 years later, the ratio will continue to increase regardless of the true safety of the model. Also shown in Figure 2 is the annual accident rate per 100,000 flight hours. Note that the accident-to-fleet-number ratio continues to climb to about 160 percent as of 1985 even though the accident rate is decreasing during the last three years. This disparity will be present for all other models and is dependent on when in the model's life cycle the ratio is computed.

## Accidents Per Departure Are More Meaningful

After comparing vastly different types of aircraft, it became apparent that some aircraft types were spending the majority of their flight time in the more hazardous flight phases of takeoffs and landings. Therefore, the accident rate per departure (or mission) was decided upon as a means to measure safety. This approach answers the question "Is the likelihood of this mission failing greater or lesser for transportation method A versus method B?" This approach is not concerned with how long A or B takes to accomplish the mission. For example, if the mission is to transport a passenger from point X to point Y, any one of the following methods of travel can qualify for the task: jet aircraft, helicopter, train, automobile, boat and walking. The number of accidents that occurred from the time of departure for each flight from any point X to the arrival at the corresponding point Y would then be deter-

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**Figure 2. Bell Model 47 accident/fleet ratio**

mined for each means of travel. This becomes the accident rate per departure for that means of transportation.

Helicopters can perform some missions that no other means of transportation can achieve. These unique missions include those that involve hovering or very slow flight, and allow very short flight times that result in a large number of takeoffs and landings. Because large airplanes spend the vast majority of their flight time in cruise flight rather than in takeoffs and landings, their exposure to flight hazards is not directly comparable. A study was done in 1981 that included a look at U.S. Federal Aviation Regulation (FAR) Part 135 unscheduled air-taxi helicopter safety related to fixed-wing air carriers[3]; the basic purpose was for relating duty time to number of daily landings, but the data is applicable to this discussion as well. The surveyed helicopter operators flew 603 single- and twin-turbine helicopters during the subject period (1977 through 1979). The percentage of singles versus twins is not available; however, the percentage of single turbines vs. twin turbines is available for 1983, which is the closest period for which that type of data is available. The 1983 U.S. registry indicates a mix of 83 percent single turbines and 17 percent twin turbines. The mix in the helicopter survey group was estimated to be similar.

## Air Travel Methods Are Compared

The accident rate per flight hour for the combined turbine helicopter fleet compared to the air carriers is shown in Figure 3A. This illustrates that the helicopter accident rate per flight hour was slightly better than that of commuter (now regional) air carriers. To account for time spent in the more hazardous phases of flight (takeoff and approach/landing), the accident rate in Figure 3B is based on number of departures (takeoffs). The resulting helicopter accident rate per 100,000 departures was 71 percent lower than FAR Part 135 commuter air carriers, and was much closer to the FAR Part 121 certificated air carriers.

Figure 3C for the fatal accident rate per departure shows that the helicopter rate was 69 percent lower than that for the commuter air carriers[4]. Figure 3D shows comparable data for fatalities per departure. In this latter case, the helicopter rate is 71 percent lower than commuter air carriers and 79 percent lower than certificated air carriers. These results indicate that the helicopter industry in general is safer than many persons believed, considering the amount of time rotary-wing aircraft spend in critical phases of flight.

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**Figure 3. Accident and fatality rate comparison (1977-1979)**

The offshore oil industry in the Gulf of Mexico presents an example of the safe operation of turbine helicopters as shown in Table 4. In 1990, there were 1,855,345 takeoffs and landings, about 1,500,000 of which occurred at offshore platforms. There were 3,958,525 passengers moved by helicopter in the Gulf during the period. Of the 619 helicopters operating in the Gulf of Mexico, 138 (22 percent) are IFR equipped, and single-turbine helicopters account for 349 (56 percent) of the total helicopter fleet. This significant usage of single-turbine helicopters indicates that single turbines are being operated safely from elevated platforms and over water.

**Table 4. Gulf of Mexico Helicopter Safety Data**

| Year | Fleet Size | No. of Accidents | Flight Hours | Departures | Accidents per 100,000 Departures | Accidents per 100,000 Flight-hours |
|---|---|---|---|---|---|---|
| 1987 | 708 | 17 | 691,655 | 2,101,850 | 0.80 | 2.46 |
| 1988 | 599 | 10 | 455,330 | 1,384,000 | 0.65 | 2.20 |
| 1989 | 608 | 9 | 515,770 | 1,885,571 | 0.48 | 1.74 |
| 1990 | 619 | 9 | 533,761 | 1,855,345 | 0.49 | 1.69 |

The use of departure exposure is accurate for determining the risk to mission accomplishment, but it is not accurate for determining safety. Safety is related to "freedom from harm, injury or loss" and should be counted in terms of time of individual occupant exposure.

## Counting Accidents Per Patient Transport

This recent safety measurement variation is used by the emergency medical services (EMS) community. It is the number of EMS aircraft accidents that occur divided by the number of patients transported during the same time period. This approach uses the EMS primary function of moving patients as the basis for comparison with the safety of other modes of moving patients. This approach is appropriate only for comparing completions of medical transport missions, not for comparing safety of the crew and patient; it is used to compare with non-patient-carrying aircraft. Figure 4[5] shows the annual EMS helicopter accident rates per 100,000 patients transported. Since many of the EMS helicopter accidents occurred without a patient aboard (e.g., en route to pickup, returning after transport or repositioning), this is a mission-oriented measurement (similar to a per-departure measurement method), rather than per human exposure method.

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**Figure 4. EMS accidents per patient transport**

## Accidents Per Passenger Mile Is Another Measurement Method

Accidents per passenger mile is another per-mission measurement with an adjustment for the distance traveled. Fixed-wing scheduled air carriers and fixed- and rotary-wing air taxi operators record passenger-carried information from revenue flights; most general aviation and helicopters do not. Thus, comparisons are seldom made in this area. Limitations of per-mission measurements are easily noted by comparing the safety of an 80-knot aircraft with a 400-knot aircraft, both having the same number of passengers and accidents per passenger mile. Some analysts interpret this as the same level of occupant safety. However, the slower machine is in the air five times as long as the faster aircraft for the same distance. Therefore, using another measurement method, the slower aircraft experiences only one fifth of the accident rate per flight hour of the faster aircraft. This dichotomy results because the primary concern is per mission and not related to per human or occupant safety; accidents per passenger mile is only meaningful if the primary concern is mission completion of moving a passenger a given distance, not the safety of the occupants.

## Accidents Per Flight Hours Is the Most Common Method

The most common method of determining safety on the basis of accidents per flight hours is accident rate per 100,000 flight hours. This accident rate per hour is the number of accidents of a given model for a specific period of time divided by the hours flown by those aircraft over that time period. Accident rate per 100,000 flight hours is a good method to determine the aircraft damage cost expected in a model fleet or the likelihood of aircraft damage. Table 5 presents the accident rates per 100,000 flight hours for U.S. general aviation fixed-wing and rotary-wing aircraft in descending order.

**Table 5. U.S.-Registered General Aviation Accident Rates (NTSB/FAA Data 1984-1988)**

| Type of Aircraft | Accident Rate per 100,000 Flight-hours |
|---|---|
| Single-piston helicopter | 17.83 |
| Single-piston airplane | 8.55 |
| Single-turbine helicopter (all) | 5.49 |
| Twin-piston airplane | 5.12 |
| Twin-turbine helicopter | 4.37 |
| Bell Model 206 single-turbine helicopter | 4.28 |

Helicopter accident rates for the 1980s from the Unites States, the United Kingdom and Canada are shown in Table 6. The time period breakdowns are similar to those in Table 3.

**Table 6. 1980s U.S., U.K., and Canadian Accident Rates (all causes) (accidents per 100,000 flight-hours)**

| Type | Canada (1982-87) | United Kingdom (1980-87) | United States (1984-88) |
|---|---|---|---|
| Single-piston | 33.53 | 73.79 | 17.83 |
| Single-turbine (all) | 9.86 | 17.12 | 5.49 |
| Twin-turbine | 4.67 | 4.83 | 4.37 |
| Bell Model 206 single-turbine | 8.70 | 14.07 | 4.28 |

## Airworthiness vs. Operational Issues Judged

The causes of accidents resulting in serious (major/fatal) occupant injury were determined[6] using NTSB data from 1982 through 1986 for single-turbine and twin-turbine civil helicopters as shown in Figure 5. Engine material failure (MF) initiated the crashes that caused 14.8 percent of the serious injuries to occupants of single-turbine helicopters, as compared to only 3.4 percent for the serious injuries to occupants of twin-turbine helicopter accidents. If only this one piece of information is considered, the obvious conclusion is that two engines are better than one.

However, next consider only the cause factor of material failures other-than engine (non-engine MF). In this case, only 11.0 percent of the seriously injured occupants were involved in single-turbine helicopter crashes initiated by non-engine material failures as compared with 31.0 percent of those in twin-turbine helicopter crashes. This is an indicator of the detrimental effects of complexity and more parts. If one were to consider only this last piece of information, the obvious approach should be that one engine is better than two — a reversal of the conclusion in the previous paragraph.

Actually, the total material failures, engine and non-engine, should be considered together, which yields percentages of seriously injured occupants due to all types of MF-caused accidents of 25.8 percent for occupants in single turbines and 34.4 percent for occupants in twins. This is consistent with more parts and complexity being present in twins. Because causes of deaths and injuries cannot be limited only to those that are engine-related, it is essential that all other factors be considered — both material failure and nonmaterial failure (i.e., human error).

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**Figure 5. Seriously injured occupants by accident cause (NTSB)**

Engine material failures represent just one aspect of material failures that cause accidents (also called airworthiness failures), as shown in Table 7 and Figure 5. Non-engine material failures that cause accidents are also represented. The single-piston accident rate per 100,000 flight hours for non-engine material failure accidents is the highest rate, followed by twin turbines, all single turbines, and with the lowest rate, the Model 206 single-turbine. Table 7 shows the combined engine and non-engine material failures (all-airworthiness failures), and indicates that the accident rate for all-airworthiness failures in twin turbines is much lower than for single pistons and slightly lower than for all single turbines. However, the twin-turbine all-airworthiness-failure accident rate is 51.4 percent higher than the single-turbine Model 206 rate. From an overall airworthiness standpoint, these figures could be used to indicate that there is no justification to require twin-turbine engines on all helicopters for all mission applications.

Comparisons of the all-airworthiness-failure accident rates of three ICAO states (United States, United Kingdom and Canada) are presented in Table 8 and Figure 6, which show the variability that is a function of the mix of aircraft models within a type and reflects varying helicopter utilization in the different ICAO states. The rates of twin turbines and Model 206s appear to be quite consistent. The single-turbine Model 206 has the lowest airworthiness accident rate in two of the three states and the second lowest in the remaining one.

## Fatal Accidents Per Flight Hours Are Questioned

Since safety is a condition of freedom from risk of harm, injury or loss, measurement of those accidents involving fatal injuries is relevant to the relationship of safety to human suffering. A fatal accident is an accident in which at least one person is fatally injured. A fatal accident rate is the number of fatal accidents per 100,000 flight hours. Figure 7[3] shows the fatal accident rates for various families of U.S. general aviation aircraft, plus three individual models for 1975 through 1979. Note that most aircraft types have approximately the same fatal accident rate. This method of measuring safety is still inaccurate because it does not account for the number of people on board that had the chance of being fatally injured. For example, regardless of a helicopter's seating capacity, there is five times the chance of someone being killed with 10 people aboard as there is with two people aboard. This is due

**Table 7. U.S.-registered Helicopter Accident Rates (Source NTSB/FAA for 1984-1988) (accidents per 100,000 flight hours)**

| Type of Aircraft | Engine Only | Non-engine Airworthiness | All Airworthiness | All Causes |
|---|---|---|---|---|
| ALL HELICOPTERS | 1.22 | 1.08 | 2.30 | 8.54 |
| Single-piston | 1.99 | 2.09 | 4.09 | 17.83 |
| Twin-turbine | 0.35 | 1.25 | 1.59 | 4.37 |
| Single-turbine (all) | 1.08 | 0.61 | 1.69 | 5.49 |
| Bell Model 206 single-turbine | 0.88 | 0.17 | 1.05 | 4.28 |

**Table 8. 1980s U.S., U.K., and Canadian All-airworthiness-failure Accident Rates (accidents per 100,000 flight hours)**

| Type | Canada (1982-87) | United Kingdom (1980-87) | United States (1984-88) |
|---|---|---|---|
| Single-piston | 8.91 | 18.45 | 4.09 |
| Single-turbine (all) | 2.12 | 4.17 | 1.69 |
| Twin-turbine | 1.27 | 1.93 | 1.59 |
| Bell Model 206 single-turbine | 1.43 | 1.17 | 1.05 |

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**Figure 6. Airworthiness failure accident rates for U.K., U.S., and Canada in the 1980s**

to the occurrence of 10 people impacting the ground in one airframe versus two people in the other airframe. Obviously, then, the number of helicopter seats is not important; the number of people aboard is important. Therefore, fatal accident rates can be misleading because they are related to aircraft airframe accidents, not to the occupants.

## Risk Around Heliports Addressed by Neighbors

Some neighbors around heliports have voiced concern about the safety of helicopters approaching or leaving a heliport. Accident statistics indicate that these concerns are unfounded. NTSB data on helicopters for 1970 through 1975 show that approximately five percent of the accidents occur in the traffic pattern or within a 1/2-mile radius of an airport or heliport. The actual risk to the surrounding neighborhood from helicopters was analyzed[7] to determine the likelihood of a helicopter accident within a 1/2-mile radius of the heliport or airport. This analysis was based on the Model 206 rate of 4.33 accidents per 100,000 flight hours in the United States for the period of 1975 through 1978. One can then calculate the likelihood of an accident within the 1/2-mile radius, which becomes a function of how many takeoffs and landings are made.

A conservative three-minute time period was assumed for time the helicopter spent flying over the 1/2-mile radius during an approach or a landing. The term "cycle" is used for the combination of a takeoff and landing (six minutes over the 1/2-mile zone). Using the average number of cycles per day for a year, the average number of years between accidents can be determined using Figure 8. For example, a busy heliport conducting five cycles per day (182.6 hours per year over the 1/2-mile radius), the expected average interval between accidents should be once in 128 years.

The likelihood of a helicopter striking a residence or building within a 1/2-mile radius of a heliport can be estimated using Figure 9.

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**Figure 7. U.S. general aviation fatal accident rates (1975-1979)**

The accident frequency used was for all helicopter accidents (single-piston, single-turbine, and twin-turbine) involved in striking a residence or building. For the five-cycle-per-day case, a helicopter striking a building or residence is estimated, on average, once every 4,000 years. Figure 10 shows the likelihood of

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**Figure 8. Helicopter accidents within 1/2 mile radius of heliport**

an on-the-ground person (not a crewman or passenger) being injured within this 1/2-mile radius. For the five-cycle-per-day case, the average interval between injuries is estimated to be about 5,000 years.

The heliport operating at five cycles per day over the period of a year is extremely busy. For a private heliport or limited-use facility that averages fewer than one cycle per day during the year, the risk is significantly lower. Using one cycle per day as an average, the likelihood of an accident in the 1/2-mile area, the likelihood of a helicopter striking a residence/building, or the likelihood of an on-the-ground person being injured are once in 635 years, 22,400 years, and 25,000 years, respectively. These average-year values in themselves are not important, but their magnitudes indicate the extremely remote threat from helicopters operating over a congested area.

If only airworthiness-failure-caused accidents

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**Figure 9. Helicopter strikes of residence or building (within 1/2 mile radius of heliport)**

are considered using the Model 206 and twin-turbine helicopter rates of Table 7, a comparison of the likelihood of an airworthiness-caused accident over a heliport's neighborhood can be done. For a constant five cycles per day usage, the expected accident frequency within the 1/2 mile radius of the heliport is an accident once in 34.4 and 52.2 years for a twin-turbine helicopter and Model 206 single-turbine helicopter, respectively. The likelihood of an accident involving either of these helicopter types is extremely remote, although one should expect the occurrence of a Model 206 accident significantly less often than a twin-turbine helicopter accident. According to these figures, there is no more justification to prohibit a Model 206 than there is to prohibit

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**Figure 10. On-the-ground personal injury (within 1/2 mile radius of heliport)**

twin-turbine helicopters from flying over congested (populated) areas.

## Study Looks for Causes of Accidents Resulting in Fatalities

A worldwide study of Bell civil and military turbine-powered helicopter accidents was conducted by the author to determine the accident causes that resulted in fatalities. The involved period was from January 1970 through March 1987. The size of the Bell turbine fleet delivered at the time was approximately 19,700 single-turbine aircraft and 1,800 twin-turbine aircraft. An engine failure was the initiating cause that resulted in six percent of all fatalities in single-turbine helicopter accidents and three percent of all fatalities in twin-turbine

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**Figure 11. Percentage of fatalities by accident initiator**

helicopter accidents as shown in Figure 11. However, the percentage of fatalities due to remaining airworthiness failures (non-engine material failures) was 12 percent and 22 percent for single-turbine and twin-turbine helicopters, respectively. Therefore, the total percentage of fatalities for all-airworthiness failures was 18 percent for single-turbine helicopters and 25 percent for twin-turbine helicopters. More complex twin-turbine helicopters, with more moving parts, will have a higher total number of material failures (engine and non-engine) with a corresponding higher total number of fatal injuries than a simpler single-turbine helicopter.

## Relative Risk of Serious Injury Considers the Individual

Accident rates compare the frequency of aircraft that must be reported as an accident because there is significant damage or there are serious personal injuries. In the majority of accidents, there is no serious injury, so the accident reporting is basically an aircraft damage mishap frequency. This information is useful in forecasting the number of aircraft expected to be damaged, repaired, replaced or other considerations based on aircraft damage. It does not address the safety of the occupant. Risk must be assigned to an individual occupant to be meaningful. Occupant safety must be determined for each individual occupant based on individual exposure. This is done with a formula that gives the relative risk of serious injury (RSI). RSI is the probability of an accident occurring multiplied by the probability of serious (major or fatal) injury. RSI = probability of an accident X probability of serious injury. It can be calculated by:

$$\text{RSI} = \frac{\text{Number of accidents}}{\text{Flight hours flown}} \times \frac{\text{Number of people with major or fatal injury}}{\text{Total number of people on board in accidents}}$$

The RSI, or an individual occupant's risk of serious injury for every 100,000 occupant hours of exposure, is shown in Figure 12 for all-airworthiness failure causes. This is the true measure of occupant safety related to the aircraft design.

Graphic not available

**Figure 12. RSI from airworthiness failures**

Therefore, an occupant's risk of serious injury due to accidents caused by all-airworthiness failures is the same in the generic single-turbine and twin-turbine helicopters. The occupant's risk in a Model 206 single-turbine helicopter is nearly half that of a generic single-turbine or a twin-turbine helicopter. The reasons that risks are generally higher in twins than singles are:

- More parts and increased complexity yield more non-engine material failures.
- There are more free-standing passenger seats and resulting seat failures in twins.
- There are more passenger seats without a shoulder harness.

- More fuel cells lead to increased likelihood of post-crash fires.

The introduction of passenger shoulder harnesses, energy attenuating seats for all occupants, and crash-resistant fuel systems may lower the RSI values. FAA Amendments 27-25 and 29-29 of November 13, 1989 requires shoulder harnesses and dynamically tested, energy attenuating seats for all occupants in future helicopter designs. FAA Notice of Proposed Rule Making (NPRM) 90-24 in progress is addressing a requirement to include crash-resistant fuel systems in large and small helicopters to minimize thermal injuries due to post-crash fires. The result could be that occupants of future helicopter designs may have even lower risk of serious injury regardless of what causes the accidents. [*This subject has been addressed by Flight Safety Foundation since the early 1960s. A successful program to develop a crash-resistant fuel tank for helicopters was conducted by FSF through its Aviation Safety Engineering and Research division in 1965, which led to a U.S. Army retrofit for approximately 5,000 helicopters. S. Harry Robertson received the FSF Admiral Luis DeFlorez Award for directing development of the system that was estimated to be capable of achieving a 70 percent reduction in loss of life due to crash fires. Helicopter crashworthiness was the focus of a 1984 FSF Regional Helicopter Safety Workshop in Rio De Janeiro, Brazil.*— Ed.]

A study of U.S. Army helicopter accidents and injuries[8] found similar results in civil helicopters. Table 9 shows the RSI for the four Army helicopters in the study. The UH-60 is the twin-turbine helicopter and the remainder are single-turbine powered. The risk of injury was found to be lower in single-turbine helicopters than in twin-turbine ones. There are several reasons for this, two of which are the greater complexity of the UH-60 and its higher speeds at impact. Again, one must be careful to evaluate all aspects of an aviation system, because improvements in one area can have detrimental effects in another. One of the goals in safety is to strive for the best mix to produce the lowest risk.

**Table 9. Relative Risk of Serious Injury in U.S. Army Helicopters**

| Type of Helicopter | RSI/100,000 Occupant Hours |
|---|---|
| UH-60 (twin-turbine) | 5.11 |
| AH-1 (single-turbine) | 4.13 |
| OH-58 (single-turbine) | 2.91 |
| UH-1 (single-turbine) | 1.36 |

## Safety Is Risk Management

To manage risk, one must first understand the total risk. Prudent risk management will reduce both probabilities in the RSI formula (probability of an accident and probability of serious injury) and achieve the lowest possible risk. Accident prevention programs attempt to reduce the probability of an accident. Training, standardization, equipment, maintenance and positive management attitude toward safety are key factors in reducing the probability of an accident. Pre-accident planning, flight following, aircraft/occupant survival gear and training, and aircraft crashworthiness address the reduction of the probability of serious injury. Totally effective accident prevention is a worthwhile goal, but an expectation of absolute elimination of accidents is unrealistic.

## Australian CAA Studies Single vs. Twin Helicopter Transfer of Marine Pilots

The Australian Civil Aviation Authority (CAA) conducted a study[9] in September 1989 to respond to a recommendation from within the CAA and elsewhere to mandate that twin-engine helicopters be utilized for transferring marine pilots between ship and shore rather than the single-engine helicopters that had been used. The study reviewed worldwide accident data. Applicable paragraphs from the study findings and conclusions are quoted below:

"The CAA believes that greater weight should be given to actual accident performance figures (where these are available) than to theoretical assumptions about fatal accident rates derived from, say, engine shutdown. For example, it would fail to account for the tradeoff between the extra reliability from having a second engine and the lower reliability of the more complex helicopter system… .

"Informal advice from the industry suggest that it would approximately double the cost of transferring marine pilots by helicopter if twin-engine helicopters were made compulsory… .

"This report does not pursue costing further because of the lack of conclusive evidence of twin-engined helicopters leading to lower fatal accident rates… .

"Marine Authorities have indicated that in some cases the higher cost of twin-engined helicopters could lead to them reverting to launches to transfer pilots, which these authorities have stated is less safe than transfer by helicopter… .

"Conclusion — The CAA believes the proposal to regulate to make it compulsory to use twin-engined helicopters for the transfer of marine pilots to and from ships should be shelved at this time. The CAA concludes that the proposal should be shelved because the present very low engine-failure accident rate is acceptable, and because there is no conclusive evidence that using twins would result in a lower fatal accident rate."

## Helicopter Accidents at Elevated Structures Are Considered

The accident histories of turbine-powered helicopters at elevated structural platforms were compared because of the ICAO Annex 6 prohibition of single-engine helicopter operation from elevated structures. Accident data from the NTSB for 1984 through 1988 were used. There were no distinctions made between type of operations being conducted, such as air transport versus aerial work. ICAO defines air transport as commercial air transport operation — an aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire. Aerial work is defined as an aircraft operation in which an aircraft is used for specialized services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertising, etc. Since the vast majority of helicopter uses are for hire or remuneration, it is not practical to use the ICAO definitions because of some overlap and the fact that the definitions as adopted vary among ICAO states.

Many helicopter operations in the United States do not fit perfectly into a particular ICAO definition; also the helicopters in use can change categories of work several times in a day. For example, a helicopter used for EMS purposes can be included in the operational categories of business, unscheduled air taxi and other work. If the helicopter owner is a government/municipal entity or if the civil operator contracts with a government agency for helicopter services, the same helicopter can also be considered an exclusive lease aircraft. The accident data should be considered in its entirety to be consistent with flight hours.

Each NTSB helicopter accident narrative for the latest available data (1984 through 1988) was used to determine all accidents that occurred on an elevated landing site or approaching/departing the elevated structure. A key word search was used for the following words in the NTSB accident narratives. These key words were

| | | |
|---|---|---|
| Elevated | Helipad | Net |
| Structure | Helideck | Rail |
| Platform | Heliport | Pad |
| Rig | Hospital | Raised |
| Roof | Building | Deck |

The resulting accidents were then separated into movable landing structures and stationary landing structures. Accidents at the movable landing structures that included landing dollies, trailers, trucks, boats, barges and portable landing structures were eliminated as not being applicable to the safety history of helicopters operating on an elevated structure. The stationary elevated structure accidents are those located at rooftops or offshore platforms.

There were no single-piston helicopter accidents related to stationary elevated platform structures, but some occurred on movable landing structures.

There were 15 single-turbine helicopter accidents at stationary elevated platform structures. Twelve were at offshore platforms and three at a rooftop sites. Of the 15 accidents, four power losses were reported. There were no material failures found during the investigation of two of these power losses. The remaining 11 clearly resulted from human causes as follows:

- Takeoff with aircraft tied down
- Landing gear caught on safety net
- Landing gear caught on deck obstruction
- Main rotor blade strike
- Blown off platform during engine start by wind
- Elevator cover not removed prior to flight.

There were 13 twin-turbine helicopter accidents at elevated platform structures. Nine were at offshore platforms and four were at rooftops. Of the nine offshore platform accidents, two were due to material failures of tail rotor drive shafts and one pylon mounting failure that allowed ground resonance. The remaining seven offshore platform accidents were human factors related as follows:

- Tail or tail rotor strike
- Main rotor strike
- Flight controls restricted (maintenance error)
- Takeoff with wheel in safety net
- Flight control loss.

Of the four rooftop accidents, two were power losses due to fuel exhaustion. A tail rotor strike accident and a flight controls restricted accident (loose object in cockpit) made up the two remaining accident causes. Two of these twin-turbine helicopter accidents on stationary elevated structures were deleted prior to the accident rate calculation because flight-hours were not available for the year of the accidents. These accidents involved two twin-turbine Aerospatiale SA-330J helicopters which were included above to show the types of accidents (13 accidents) but are deleted in Table 10 when accident rates are used (11 accidents). All single-turbine accidents (which were Model 206s) on stationary elevated structures were usable accidents.

Table 10 shows the U.S. elevated structure helicopter accident history for 1984 through 1988. This table also identifies the stationary elevated structure accidents that were related to power losses. For all accidents at elevated structures, the accident rates for the single-turbine and twin-turbine helicopters were 0.21 and 0.76 per 100,000 flight hours, respectively. Therefore, the single-turbine rate was 72.4 percent lower than the rate for twin-turbine helicopters. Considering only those related to power losses, the single-turbine and twin-turbine helicopter accident rates were 0.071 and 0.139 per 100,000 flight hours, respectively. The single-turbine rate for power loss accidents was 48.9 percent lower than the twin-turbine rate.

The second part of Table 10 is similar to the first, except that the fleet flight hours used were for only the models that were involved in elevated structure accidents. In this analysis, the single-turbine and twin-turbine accident rates for all causes were 0.29 and 1.18 per 100,000 flight hours, respectively. The single-turbine rate was 75.4 percent lower than the twin-turbine rate. Considering the power-loss accidents, the single-turbine and twin-turbine accident rates were 0.096 and 0.214 per 100,000 flight hours, respectively. The single-turbine rate for power-loss accidents was 55.1 percent lower than the twin-turbine rate. Thus, the actual helicopter accident experience related to helicopter operations at a stationary elevated structure does not justify the prohibition of single-engine helicopters in such operations.

**Table 10. U.S. Elevated Structure Turbine Helicopter Accident History (1984-1988)**

| Type of Aircraft | Fleet Flight Hours | All Accidents | All Causes Rate* | Power-loss Accidents | Power-loss Accident Rate* |
|---|---|---|---|---|---|
| Single | 7,035,846 | 15 | 0.21 | 5 | 0.071 |
| Twin | 1,442,116 | 11 | 0.76 | 2 | 0.139 |
| Using hours of aircraft models involved in accidents: | | | | | |
| Single | | | | | |
| Bell Model 206 | 5,215,001 | 15 | 0.29 | 5 | 0.096 |
| Twin | | | | | |
| 222 | 932,438 | 11 | 1.18 | 2 | 0.214 |
| AS355 | | | | | |
| B0105 | | | | | |
| S58T | | | | | |
| S76 | | | | | |

* Accidents per 100,000 flight hours

## Evaluating Offshore Helicopter Operator Experience

Petroleum Helicopters Inc. (PHI) is the largest commercial helicopter operator in the world. Most of the company's flying is for offshore oil support and is an excellent example of safe helicopter operations in a difficult environment. The latest PHI-furnished flight-hour information and NTSB accident data on PHI helicopters from 1984 through 1988 indicate that single-turbine helicopters are being operated safely over water and onto elevated platforms. PHI flight hours in Table 11 show that 66.1 percent of PHI's flying was in single-turbine helicopters. Table 12 compares the PHI accident rates for all causes with the U.S. civil helicopter fleet rates for all causes. The PHI accident rate for single-turbine helicopters was 65.8 percent and 62.2 percent lower than the general U.S. single-turbine and twin-turbine helicopter rates, respectively. This illustrates that a safe operation can be conducted using single-turbine helicopters without operational restrictions as proposed by the recent ICAO Annex 6, Amendment 1 change.

**Table 11. Petroleum Helicopter Inc (PHI) Flight Hours (1984-1988)**

| Type of Aircraft | Flight Hours | Percentage of Total |
|---|---|---|
| Single-turbine | 1,064,439 | 66.1 |
| Twin-turbine | 545,670 | 33.9 |
| Total | 1,610,117 | 100 |
| Bell Model 206 only | 982,611 | 61.0 |

## Time of Accident, Day vs. Night, Considered as Factors

Since the actual hours flown at specific times of the 24-hour day are not known, it is difficult to determine relative safety of night flight versus daylight flight. However, it is possible to approximate the distribution of flying at night by considering the random nature of material failures. For the period of 1982 through 1988, the U.S. distribution of accidents (all causes) by the time of day from NTSB data are shown in Figure 13. The breakpoints between light and dark were assumed at 0600 and 1959 hours. This distribution of accidents is considered conservative, because most flying is done during the summer months

**Table 12. Petroleum Helicopter Inc. (PHI) vs. U.S. Helicopter Accident Rates* (accidents from NTSB, hours from FAA and PHI, 1984-88)**

| Type of Aircraft | U.S. (NTSB/FAA) | PHI (NTSB/PHI) |
|---|---|---|
| Single-turbine | 5.49 | 1.88 |
| Twin-turbine | 4.37 | 1.65 |
| Bell Model 206 only | 4.28 | 1.73 |

* Accidents per 100,000 flight hours

when the length of daylight is highest. This indicates that 91.8 percent and 82.8 percent of all single-turbine and twin-turbine helicopter accidents, respectively, are occurring in daylight hours.

Figure 14 shows the time of accident distribution of airworthiness-failure accidents (all material failures including the engine). For all-airworthiness-failure accidents, 98.2 percent and 94.1 percent of single-turbine and twin-turbine helicopter accidents, respectively, are occurring in daylight hours. The two figures have similar distribution; therefore, accidents due to material failures do not appear to be adversely affected by lighting, and therefore, there is insufficient justification to prohibit single-engine helicopters from flying at night.

The major difference in helicopter and fixed-wing aircraft emergency landings is that the fixed-wing aircraft requirement for a long cleared landing site increases the likelihood of injury during the final phase of the emergency. Conversely, a helicopter (regardless of the number of engines) can use a landing site that is quite small in comparison to the needs of the fixed-wing aircraft. Likewise, visibility at night is not as critical in a helicopter as in a fixed-wing aircraft due to the helicopter's lower speed and greater maneuverability during autorotation.

**Graphic not available**

**Figure 13. Time of accidents due to all causes**

## Likelihood of a Material Failure Accident at Night Examined

Assuming a Model 206 and a twin-turbine helicopter flew during 10 hours of darkness every night throughout one full year, each helicopter would fly 3,652.5 hours during that time. Using the NTSB/FAA accident data for 1984 through 1988 (Table 7), the likelihood of an accident due to a material failure (which includes engine) for the twin-turbine helicopter is estimated at once in 17.2 years, whereas the likelihood in a Model 206 is estimated at once in 26.1 years. Thus, the likelihood of any material-failure-caused accident is 51.4 percent higher in a twin-turbine helicopter than in the single-turbine Model 206. There is insufficient justification to support the prohibition of night flights using single-engine helicopters with respect to material failures.

**Graphic not available**

**Figure 14. Time of accidents due to airworthiness failures**

## Human Error Accidents Related to Weather Considered

Analysis of human error accidents involving weather show a changing trend in the United States. NTSB accident data and FAA flight hours for 1984 through 1988 were divided into an early period of 1984 through 1986 and compared to the later period of 1987 and 1988. The results are represented in Table 13. The year 1987 was when Bell Helicopter Textron Inc. began concentrated safety training programs to reduce human error accidents. The range of human error accident rate reductions due to poor weather decisions in the most recent time period have been significantly reduced by between 45 and 72 percent. Bell believes that this reduction is due to safety training, not to mandatory regulations.

## Bell Institutes Safety Training Approach

Accident data analyses can be used to determine if safety programs or other factors are making a change in the accident frequencies. Two out of three accidents are not caused by airworthiness failure but are basically due to human error. Accidents caused by human error (otherwise called pilot error) present an extremely complex problem with a large number of root causes and an even larger number of potential solutions. Engineers and regulatory agencies are comfortable working on mechanical problems because their performance and failure modes are fairly predictable. Thus, aviation safety efforts in the past have made significant gains in minimizing airworthiness failures.

More attention is now being made toward the understanding, and eventual reduction, of human error accidents. A worldwide engineering study in 1985 and 1986 into human error accidents of Bell civil helicopter models found that poor judgment was the common factor in all of these accidents[2]. Two directions of concentrated effort at Bell were launched in 1987 to aggressively attack the complex human error problem, with the emphasis on judgment training.

The company's Human Factors Engineering staff took the approach of developing an artificial intelligence-based software program that would allow a pilot to use a personal computer (PC) as a judgment (decision-making) simulator. This program, called the Cockpit Emergency Procedures Expert Trainer (CEPET), also includes emergency procedures training. A CEPET was developed for the Bell JetRanger (206BIII) and LongRanger (206L-3), with one

**Table 13. U.S. Human Errors Accidents Involving Weather**

| | Single-piston | Single-turbine | Twin-turbine | Bell Model 206 Single-turbine |
|---|---|---|---|---|
| Flight Hours | | | | |
| 1984-86 | 1,899,081 | 4,167,156 | 821,679 | 2,997,911 |
| 1987-88 | 1,062,171 | 2,868,690 | 620,437 | 2,217,090 |
| HE WX Accidents | | | | |
| 1984-86 | 26 | 40 | 7 | 25 |
| 1987-88 | 8 | 8 | 2 | 5 |
| HE WX Accidents per 100,000 Flight Hours | | | | |
| 1984-86 | 1.37 | 0.96 | 0.85 | 0.83 |
| 1987-88 | 0.75 | 0.28 | 0.32 | 0.23 |
| HE WX Rate Reduction | -45.3% | -70.8% | -62.4% | -72.3% |

HE = Human Error

WX = Weather

**Table 14. Worldwide Bell Turbine Accident Rates (per 100,000 flight hours)**

| Aircraft and Period | Flight Hours | Causes of Accidents: Human Error | Non-human and Unknown | All Causes |
|---|---|---|---|---|
| Bell Model 206 | | | | |
| 1983-1986 | 7,903,072 | 3.90 | 2.05 | 5.95 |
| 1987-1990 | 9,341,573 | 2.49 | 1.89 | 4.38 |
| Percent change | | -36.25% | -7.8% | -26.3% |
| Bell Medium Helicopters | | | | |
| 1983-1986 | 2,438,515 | 2.62 | 2.01 | 4.63 |
| 1987-1990 | 2,472,091 | 2.31 | 2.39 | 4.69 |
| Percent change | | -11.8% | +18.9% | +1.3% |

completed late in 1990 for the Model 212/412. A CEPET package is provided with each new Bell aircraft delivery; pilots can also purchase a separate CEPET package.

The other direction focused on concentrated safety education. Bell's System Safety Engineering personnel developed a three-hour safety briefing for immediate use with groups of pilots and managers. This safety briefing includes how to measure one's risk, what happens in a crash, how one can improve the chances of survival, causes of accidents, root causes of human error, and judgment training. Judgment training emphasizes the use of all resources available to the pilot

The emphasis of judgment training is on situational awareness and internal pilot monitoring. Portions of the FAA study, DOT/FAA/PM-86/45, "Aeronautical Decision Making for Helicopter Pilots[10]," are used in this safety briefing and the FAA report is given to the student for further self study. The safety briefing is given at operator meetings and regional safety seminars, and is included in Bell's weekly Model 206 pilot's ground school as part of the HELIPROPS (Helicopter Professional Pilots Safety) program.

The company's chief training pilot also conducts customer HELIPROPS safety briefings on safety awareness, professionalism and management's role in safety. These safety briefings are held at the factory, customer sites and regional safety seminars. The Customer Support and Service Department (CSSD) initiated the HELIPROPS program to add continuity and coordination of these safety education efforts in 1988.

The worldwide effects of this four-year safety education effort on the human error accident rate since the Model 206 effort was initiated in 1987 is shown in Table 14. There have been more than 5,000 Model 206 series helicopters produced, or 70 percent of Bell's entire civil turbine helicopter model fleet. Bell also conducts flight training in Model 206s. Based on these two factors, the concentrated safety education effort has been directed at Model 206 pilots. For comparison, the same worldwide data for Bell's medium civil helicopters models (204B, 205A1, 214B, 212, 214ST, 222, and 412) are also shown in Table 14. These medium helicopter data indicate some reductions in human error causes, but were offset by non-human-error causes; thus the accident rate for all causes was basically the same during the two four-year periods.

Conversely, accident rates due to human error in a Model 206 for the four-year period before the initiation of this safety effort (1983-1986) compared with the four-year period since then (1987-1990) show a 36.2 percent reduction in human error accidents. This is a significant safety improvement and only a small portion of the world's Model 206 pilots have been reached so far. The overall (all causes) Model 206 acci-

**Table 15. Safety Education Effects on Human Error Accident Rates NTSB/FAA (U.S.-registered)**

| Type of Helicopter | Rate* Before (1984-86) | Rate* Since (1987-88) | Percent Changes |
|---|---|---|---|
| Single-piston | 11.16 | 10.92 | -2.2% |
| Other Than Bell Model 206 single-turbine | 4.11 | 3.07 | -25.3% |
| Twin-turbine | 2.56 | 1.61 | -37.1% |
| Bell Model 206 single-turbine** | 3.40 | 1.76 | -48.2% |

* Human error accidents per 100,000 hours

** Concentrated HELIPROPS safety education

dent rate was reduced by 26.3 percent. Because many pilots fly other helicopters in addition to the Bell Model 206, some spillover of the beneficial effects of judgement training can be expected that should affect the overall helicopter industry accident rate.

Judgment training is also called pilot decision making (PDM) and aeronautical decision making (ADM). The Canadian government is integrating PDM into its pilot training requirements as of April 1991. PHI introduced judgment training as an integral part of its internal training about when Bell introduced its judgment training program in 1987, and has subsequently cut its accident rate in half. The company expects further accident rate reductions as the program continues. Judgment training has more safety improvement potential than the total elimination of all-airworthiness failure causes.

A reflection of the success of the safety education efforts by several manufacturers of helicopters in the United States is found in Table 15. This shows a significant reduction in human error accident rates in the turbine helicopter fleet, although more work is needed in the single-piston fleet. Since safety education is an ongoing effort, it will take several years to benefit all helicopter pilots.

## The Helicopter's Uniqueness Must Be Taken into Account

Helicopters behave differently than fixed-wing aircraft after an engine failure. The helicopter's ability to autorotate allows the selection of suitable landing sites and a low-speed emergency landing from an engine failure.

Safety decisions on any one aspect of helicopters should not be made without considering all the other safety aspects, as well as the human causes. The safety measurement method to consider is strictly determined by the subject of primary concern. The denominator of the frequency rate will include this primary concern. If aircraft damage frequency is the primary concern, then an accident per aircraft flight hour method is appropriate. If the mission is the primary concern, then accidents per mission (takeoff, departure, takeoff, flight, trip, passenger mile or patient transport) is appropriate. If the primary concern is the risk of an accident in a neighborhood without regard to the aircraft occupants, then years-between-accidents measurement for that specific neighborhood exposure is appropriate. With the safety of the aircraft occupant as the primary concern, the relative risk of serious injury per occupant flight hour is the best method.♦

## References


1. Amendment No. 1 to International Standards and Recommended Practices, Operation of Aircraft, Annex 6 to the Convention on International Civil Aviation, Part III, International Operations — Helicopters, International Civil Aviation Organization (ICAO), March 1990.

2. Fox, R. G., "Helicopter Accident Trends," American Helicopter Society / Helicopter Association International / FAA Seminar, Vertical Flight Training Needs and Solutions, September 1987.

3. Fox, R. G., "Relative Risk, the True Measure of Safety," Flight Safety Foundation, *Proceedings of the 28th Corporate Aviation Safety Seminar*, April 1983.

4. Commuter Airline Safety, Special Study, National Transportation Safety Board, Report NTSB-AAS-80-1.

5. Collett, H. F., "Accident Trends for Air Medical Helicopters," *Hospital Aviation*, February 1989.

6. Fox, R. G., "Helicopter Crashworthiness," Flight Safety Foundation, *Proceedings of the 34th Corporate Aviation Safety Seminar*, April 1989.

7. Fox, R. G., "Helicopters Are Safe Neighbors," Helicopter Association International, *1990 Helicopter Annual*, January 1990.

8. Shanahan, D. F. and M. O., "Injury in U.S. Army Helicopter Crashes, October 1979 to September 1985," *Journal of Trauma*, April 1989.

9. Pardy, B. T., "Preliminary Safety Impact Statement Twin-Engined Helicopters for Marine Pilot Transfers," Australian Civil Aviation Authority, Report A SR-2, September 1989.

10. Adams, R., and Thompson, J., "Aeronautical Decision Making for Helicopter Pilots," Federal Aviation Administration, DOT/FAA/PM-86/45, February 1987.

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*Fox is a member of the General Aviation Safety Panel for seat restraints and post-crash fire protection, and participates in the SAE committees on seat and restraint requirements. He is a lecturer on crash survival and human performance at the Bell Training School and the U.S. Federal Aviation Administration Helicopter Safety and Accident Investigation course.*

# Near Midair Collisions, Operational Errors and Pilot Deviations

*by*
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The U.S. Federal Aviation Administration (FAA) has reported that near midair collision incidents, air traffic controller operational errors and pilot deviations continued to show a decline in 1990 as compared with those recorded in previous years, but runway incursions showed an increase two years in a row. This information was provided in the final report, 1990 Aviation Safety Statistics, prepared by the FAA's office of the assistant administrator for aviation safety.

A near midair collision refers to an incident associated with the operation of an aircraft during which a possibility of collision occurs as a result of a proximity of less than 500 feet from another aircraft, or an official report is received from an air crew member stating that a collision hazard existed between two or more aircraft. The 452 near midair collisions, reported during last year, were 606 (57) percent less than the 1,058 recorded in 1987 and was the lowest level since 1984. The 1990 figure represents the third consecutive year that near midair collision reports dropped since the FAA upgraded its reporting system in 1985 to ensure more complete data collection on these incidents.

**Graphic not available**

**Figure 1. Near Midair Collisions 1985-1990**

Figure 1 shows the downtrend of near midair collision incidents for the past six years, and Figure 2 illustrates how midair collisions happened more often in the summertime than any other time of the year. In the months of July, August and September, air traffic for both civil and military were the heaviest during each year.

An operational error refers to an occurrence attributable to an element of the air traffic control system which results in less than the applicable separation minima between two or more aircraft, or between an aircraft and terrain or obstacles and obstructions as required by FAA Handbook 7110.65 and supplemental instructions. Obstructions include vehicles, equipment, personnel or runways. Beginning in 1984, the FAA began installing computer software in all domestic air route traffic control centers that automatically records violations of the agency's aircraft separation standards. The 881 operational errors made by

**Graphic not available**

**Figure 2. Near Midair Collision Reports by Month 1985-1990**

controllers in 1990 were the lowest since 1983. Figure 3 shows the trend of air traffic controller operational errors for the past six years. Air traffic controller operational errors dropped from a high of 1,406 in 1985 to 881 in 1990, down by 524 errors, or 37 percent. Figure 4 shows the occurrence of operational errors by

**Graphic not available**

**Figure 3. Air Traffic Controller Operational Errors 1985-1990**

**Graphic not available**

**Figure 4. Air Traffic Controller Operational Errors by Month 1985-1990**

month for the past six years. Note that the monthly frequency of operational errors appears to have an almost identical pattern each year. Air traffic controllers usually committed fewer operational errors in January and February. The frequencies of operational errors increased in March and April, dropped in May and continued to rise into July; they went up again in August and gradually declined from September to the end of the year.

Pilot deviation refers to those actions of a pilot that result in the violation of U.S. Federal Aviation Regulations or airspace violation of a North American Air Defense (NORAD) Command Air Defense Identification Zone (ADIZ) tolerance. Figure 5 shows the trend of pilot deviations over the past six years. Pilot deviations increased from 1,800 in 1985 to 3,625 in 1987, the highest in recent years, then decreased to 2,460 in 1990. Although the 2,460 pilot deviations in 1990 were only slightly lower than those in 1989, the figure is well below the 1987 level. Figure 6 shows the annual frequency of pilot deviations by month which also indicates that pilots committed more errors during the summer of each year.

Runway incursion refers to an occurrence at an airport involving an aircraft, vehicle, per-

Graphic not available

**Figure 5. Pilot Deviations 1985-1990**

Graphic not available

**Figure 7. Runway Incursions 1987-1990**

son or object on the ground that created a collision hazard or resulted in loss of proper separation with an aircraft taking off, intending to take off, landing or intending to land. Against the downtrends of other safety indicators, runway incursions steadily increased from 179 in 1988, to 233 in 1989 and to 267 in 1990. Figures 7 and 8 show the trend and annual frequency distribution by month of runway incursions. Almost every year in the past four years, runway incursions were relatively higher in March, June, August, October and December and often relatively lower in February, April, July, September and November. During the most recent 15 months, there were five fatal accidents at U.S. airports, involving U.S. air carrier aircraft, accounting for 33 fatalities. That was the highest number of fatal accidents in any 15-month period in U.S. air carrier safety records. Three of the fatal accidents were ground collisions between aircraft. One pedestrian was killed on a runway by an aircraft during takeoff and one mechanic was fatally injured by a tug during towing. ♦

Graphic not available

**Figure 6. Pilot Deviations by Month 1985-1990**

Graphic not available

**Figure 8. Runway Incursions by Month 1987-1990**

# Reports Received at FSF Jerry Lederer Aviation Safety Library

## Reference

*Federal Aviation Regulations, Part 135-Air Taxi Operators and Commercial Operators*; Change 38.— Washington, D.C. : United States. Federal Aviation Administration [1991].

Summary: This change incorporates Special Federal Aviation Regulation (SFAR) 38-6, Certification and Operating Requirements, effective June 5, 1990, and Amendment No. 135-39, Minimum Equipment Lists (MEL), effective June 20, 1991, in Federal Aviation Regulation Part 135.

## Reports

*Aircraft Accident Report: Avianca, the Airline of Colombia, Boeing 707-321B, HK 2016, Fuel Exhaustion, Cove Neck, New York, January 25, 1990* / United States. National Transportation Safety Board. — Washington, D.C. : U.S. National Transportation Safety Board; Springfield, Virginia, U.S. : Available through NTIS*, Adopted April 30, 1991, Notation: 5255B. Report NTSB/AAR-91/04; NTIS PB 91-910404. vi, 6 p. : ill.

Key Words

1. Aeronautics — Accidents — 1990.
2. Aeronautics — Accidents — Fuel Exhaustion.
3. Aeronautics — Accidents — Pilot Language Proficiency.
4. Aeronautics — Accidents — Air Traffic Control Procedures.
5. Aeronautics — Accidents — Pilot Fatigue.
6. Aeronautics — Accidents — Windshear.
7. Aeronautics — Accidents — Flight Planning.
8. Aeronautics — Accidents — Takeoff/Landing.
9. Avianca Airlines — Accidents — 1990.

Summary: On January 25, 1990, at approximately 2134 eastern standard time, Avianca Airlines flight 052, a Boeing 707-321B with Colombian registration HK 2016, crashed in a wooded residential area in Cove Neck, Long Island, New York. AVA052 was a scheduled international passenger flight from Bogota, Colombia, to John F. Kennedy International Airport, New York, with an intermediate stop at Jose Maria Cordova Airport, near Medillin, Colombia. Of the 158 persons aboard, 73 were fatally injured, including all three flight crew and five of six cabin crew members. Because of poor weather conditions in the northeastern part of the United States, the flight crew was placed in holding three times by air traffic control for a total of about 1 hour and 17 minutes. During the third period of holding, the flight crew reported that the airplane could not hold longer than five minutes, that it was running out of fuel, and that it could not reach its alternate airport, Boston-Logan International. Subsequently, the flight crew executed a missed approach to John F. Kennedy International Airport. While trying to return to the airport, the airplane experienced a loss of power from all four engines and crashed approximately 16 miles from the airport.

The NTSB determined that the probable cause of this accident was the failure of the flight crew to adequately manage the aircraft's fuel load, and their failure to communicate an emergency fuel situation to air traffic control before fuel exhaustion occurred. Contributing to the accident was the flight crew's failure to use an airline operational control dispatch system to assist them during the international flight into a high-density airport in poor weather. Also contributing to the accident was inadequate traffic flow management by the Federal Aviation Administration and the lack of standardized understandable terminology for pilots and controllers for minimum and emergency fuel states.

Recommendations A-91-33 through A-91-38 and A-90-9 through A-90-11 were issued as a result of this accident. [executive summary]

*Aircraft Maintenance: Additional FAA Oversight Needed of Aging Aircraft Repairs.* Vol. I and II. Report to the Chairman, Subcommittee on Aviation, Committee on Public Works and Transportation, House of Representatives/United States. General Accounting Office (GAO). — Washington, D.C., U.S. : U.S. General Accounting Office*, May 24, 1991.Report GAO/RCED-91-91A and GAO/RCED-91-91B, B-242727.71 p. ; 57 p. ; ill.

Key Words
1. Air Planes — Maintenance and Repair — United States.
2. Jet Transports — Maintenance and Repair — United States.
3. Aeronautics, Commercial — Safety Measures — United States.

Summary: Volume I describes that portion of the U.S. aircraft repair industry that performs heavy airframe maintenance on large transport aircraft. Specifically, it examines increases in demand for heavy airframe maintenance; constraints on supply, including parts, skilled mechanics, and hangar space; and air carriers' efforts to comply with new requirements for aging aircraft and the Federal Aviation Administration's (FAA) oversight of air carriers as they attempt to comply with the new rules. Volume II provides the questionnaire response of the 48 air carriers and 35 independent repair stations participating in the review on the issues examined in Volume 1. [Introductory letter]

To improve FAA's oversight of aging aircraft AD compliance, GAO recommends that the Secretary of Transportation direct the Administrator, FAA, to (1) require domestic air carriers to submit periodic reports on their implementation of FAA's new rules for aging aircraft, (2) submit to the chairmen of the aviation authorization subcommittees in the U.S. House and Senate a semiannual report on the industry's progress in complying with FAA's aging aircraft mandates, and (3) explore options for extending compliance deadlines or granting alternative means of compliance when warranted by resource shortages and ensured airworthiness of each aircraft. [recommendations]

*Annual Review of Aircraft Accident Data. U.S. Air Carrier Operations, Calendar Year 1988*/United States. National Transportation Safety Board. — Washington, D.C. : U.S. National Transportation Safety Board; Springfield, Virginia, U.S. : Available through NTIS*, April 18, 1991.Report NTSB/ARC-91/01, NTIS PB91-176040. 76 p.; charts, graphs.

Key Words
1. Aeronautics — Accidents — 1988.
2. Aeronautics — Accidents — Statistics — 1988.
3. Aeronautics — Accidents — United States— 1988.
4. Aeronautics, Commercial — Accidents— United States.

Contents: Introduction — 14 CFR 121, 125, 127 Operations — Scheduled 14 CFR 135 Operations — Nonscheduled 14 CFR 135 Operations — Midair Collision Accidents — Explanatory Notes — Cause/Factor Table-14 CFR 121, 125, 127 —Cause/Factor Table-Scheduled 14 CFR 135 — Cause/Factor Table-Nonscheduled 14 CFR 135 — NTSB Form 6120.4.

Summary: Presents the record of aviation accidents involving revenue operations of U.S. air carriers including commuter air carriers and on-demand air taxis for calendar year 1988. [author abstract]

*Aviation Safety: Changes Needed in FAA's Service Difficulty Reporting Program.* Report to the Chairman, Subcommittee on Aviation, Committee on Commerce, Science, and Transportation, U.S. Senate/United States. General Accounting Office. — Washington, D.C., U.S.: U.S. General Accounting Office*, March, 1991. Report GAO/RCED-91-24; B238393. 16 p.

Key Words
1. Jet Transports — Airworthiness.
2. Jet Transports — Inspection — United States.
3. Aeronautics — Accidents — United States.

Summary: GAO evaluated the effectiveness of the part of the Federal Aviation Administration's (FAA) Service Difficulty Report (SDR) program related to large, airline-operated aircraft. GAO found that several factors stemming primarily from FAA's management inattention limit the program's usefulness. Information that one airline considers reportable may go unreported by another airline; useful information does not reach subscribers for more than six weeks because of delays in manual data processing through a paper-based system; FAA does not analyze the data, as required by FAA policy, to detect malfunction trends in specific aircraft models or focus the efforts of FAA's inspection work force because of insufficient staff and unreliable data. Alternatives do exist, such as major equipment manufacturers managing the program. Several policy issues regarding cost, liability and the manufacturers' roles in regulating air safety need to be addressed before an alternative is chosen. [Results in brief]

*Donning Times and Flotation Characteristics of Infant Life Preservers:* Four Representative Types. Final Report/Gordon E. Funkhouser and Gregory W. Fairlie (Civil Aeromedical Institute). — Washington, D.C. : United States. Federal Aviation Administration Office of Aviation Medicine; Springfield, Virginia, U.S.: Available through NTIS*, April, 1991. Report DOT/FAA/AM-91/6. 12 p. : ill.

Key Words
1. Aeronautics, Commercial — Safety Measures.
2. Survival (After Airplane Accidents, Shipwrecks, etc.).
3. Life-preservers.
4. Drowning — Prevention — Equipment and Supplies.
5. Infants.

Summary: Four currently available representative types of infant life preservers were tested to assess the donning times and flotation characteristics for infant subjects (six months to two years old). Donning times were recorded from the time the unwrapped device was handed to the parent until the last connection or adjustment was made. The device that was most quickly donned was an inflatable type with a vest attached to the top of the upper chamber (median donning time was 28.8 seconds). This infant life preserver also exhibited good body support with the head well above the water. The two fixed-foam devices were designed to have approximately one-third of the buoyancy of the two inflatable types and relied on assistance from an adult to maintain the infant in a safe flotation attitude. It appears that the fixed-foam infant life preservers would provide more thermal protection than the inflatable life preservers. [author abstract]

*Electronic Checklists: Evaluation of Two Levels of Automation*/Everett Palmer (U.S. National Aeronautics and Space Administration (NASA)-Ames Research Center) and Asaf Degani (San Jose State Foundation). — Moffett Field, California, U.S.: NASA Ames Research Center, 1991. 6 p. ; ill.

Key Words
1. Airplanes — Piloting — Automation.
2. Airplanes — Piloting — Checklists.
3. Airplanes — Cockpits — Automation.

Notes

Paper presented at the Sixth International Symposium on Aviation Psychology, April 29-May 2, 1991, Columbus, Ohio, U.S..

Summary: Two versions of an electronic checklist, differing in degree of pilot involvement in conducting the checklists, and a paper checklist (as a control condition) were evaluated in line-oriented simulation. Two aircrews from one major air carrier flew a routine, four leg, short-haul trip. This paper presents and discusses the portion of the experiment that was concerned with measuring the effect of the degree of automation on the crews' performance. It discusses and presents evidence for a potential downside of implementing an electronic checklist that is designed to provide fully redundant monitoring of human procedure execution and monitoring. [modified author abstract]

*Philosophy, Policies, and Procedures: The Three P's of Flight-deck Operations* /Asaf Degani (San

Jose State University Foundation) and Earl L. Wiener (University of Miami). — Moffett Field, California, U.S.: NASA Ames Research Center, 1991. 8 p.

Key Words
1. Aeronautics — Accidents — Human Factors.
2. Aeronautics — Accidents.
3. Airplanes — Operational Procedures.
3. Airplanes — Piloting — Human Factors.

Notes

Paper presented at the Sixth International Symposium on Aviation Psychology, April 29-May 2, 1991, Columbus, Ohio, U.S..

Research was supported by NASA Ames Research Center Grants NCC2-327 to the San Jose State University Foundation and Grant NCA2-441 to the University of Miami.

Includes references.

Summary: Standard operating procedures (SOP) are drafted and provided to flight crews to dictate the manner in which tasks are carried out. Failure to conform to SOP is frequently listed as the cause of violations, incidents and accidents. However, procedures are often designed piecemeal, rather than being based on a sound philosophy of operations and policies that follow from such a philosophy. A framework of philosophy, policies and procedures is proposed. [author abstract]

*The Use and Design of flight crew Checklists and Manuals. Final Report*/John W. Turner (EF&G Dynatrend) and M. Stephen Huntley Jr. (U.S. Department of Transportation Research and Special Programs Administration). — Washington, D.C. : United States. Federal Aviation Administration Office of Aviation Medicine; Springfield, Virginia, U.S. : Available through NTIS*, April, 1991. Report DOT/FAA/AM-91/7. 75 p. : ill.

Key Words
1. Airplanes — Piloting — Checklists.
2. Airplanes — Piloting — Handbooks, Manuals, etc.
3. Airlines — Operational Procedures.
4. Air Pilots — Handbooks, Manuals, etc.
5. Aeronautics, Commercial — Safety Measures.

Summary: A survey of aircraft checklists and flight manuals was conducted to identify impediments to their use and to determine if standards or guidelines for their design were needed. Information for this purpose was collected through the review of checklists and manuals from six Part 121 and nine Part 135 carriers, review of NTSB and Aviation Safety Reporting System (ASRS) reports, analysis of an Air Line Pilots Association (ALPA) survey of air carrier pilots, and by direct observation in air carrier cockpits. The survey revealed that some checklists and manuals were difficult to locate and were poorly designed for use in the cockpit environment, the use of checklists by flight crews was not always well defined, the use of checklists interfered with other flight operations and flight operations often made it difficult to use checklists effectively. The report contains recommendations for the format and content of checklists and manuals, their use by flight crews, and areas of research relevant to checklist design. [author abstract]

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# Accident/Incident Briefs

*This information is intended to provide an awareness of problem areas through which such occurrences may be prevented in the future. Accident/incident briefs are based upon preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be accurate.*

## Who Left the Door Open?

*Boeing 747: Minor damage. No injuries.*

The widebody aircraft was preparing to depart the terminal for a regularly scheduled flight. The flight was being operated during the daytime, early in the afternoon.

After all pre-taxi checks had been completed, the aircraft was being pushed back from its parking position at the terminal gate. A left front passenger door, that had inadvertently been left open, collided with the jetway and was damaged as the aircraft rolled back. The aircraft had to be taken out of service for repairs and the passengers transferred to other flights.

## Overshot Altitude While Looking for Traffic

*Boeing 737: No damage. No injuries.*

The air carrier had just departed the airport and was climbing to its initially assigned altitude of 14,000 feet. The captain was providing initial operating experience for a new first officer who was flying the aircraft.

As the aircraft approached the 13,000-foot level, air traffic control (ATC) issued a traffic advisory for a target at 11 o'clock at 15,000 feet. At first, neither pilot was able to see the reported traffic and both were distracted looking for it. As a result, the aircraft continued climbing through its assigned clearance level of 14,000 feet. The pilots received an altitude alert, and an ATC altitude deviation advisory at 14,300 feet and were able to reverse the climb by 14,500 feet. Despite a quick return to the cleared altitude, legal vertical separation of 500 feet had been lost between the 737 and the other aircraft.

Among lessons learned are ensuring that someone is flying the aircraft at all times, that the rate of climb is closely monitored during the last 1,000 feet of climb, and that procedures be established for receiving clearances and setting the altitude alert system.

## Strange Noise at Night Makes Flight Interesting

*Fokker F.27 Friendship: No damage. No injuries.*

The aircraft was departing on a scheduled flight during the night. The aircraft and systems had checked OK during preflight checks.

However, after rotation the noise level in the cockpit increased substantially. The sound became worse as the aircraft increased speed during the climbout. The flight crew investigated the sound and the noise appeared to be coming from the first officer's side window. The crew reduced the airspeed and it was determined that the first officer's window was ajar, even though the locking handle was in the down and locked position. When it had been visually inspected during the preflight checks, the window had appeared to be closed; but the locking bolts had not been engaged properly.

The first officer opened the window and closed it properly and the noise stopped. The flight was continued without further incident.

## Too Busy Talking To Passenger

*Piper PA-31 Navajo Chieftain: Substantial damage. No injuries.*

The aircraft was inbound on an approach. There were a pilot and two passengers aboard. The pilot had total of 13,000 flying hours, 1,500 in type and 200 during the previous three months.

The aircraft was cleared for a straight-in approach to land. The pilot was explaining the pre-landing checks to one of the passengers. During the conversation, the pilot noticed that the nose gear landing lights were not illuminated. Because he thought the landing gear had been placed down, he assumed that the landing gear indicator bulbs had failed.

The pilot continued the approach — and the aircraft landed with the landing gear retracted. There was no fire, but the aircraft sustained substantial damage to the propellers, flaps and underside of the fuselage. There were no injuries to the occupants.

The pilot reported that he forgot to lower the landing gear, and that the power setting was too high for the warning horn to actuate.

Corporate Executive

## Man-made Windshear Snaps Gear Leg

*Cessna 303 Crusader: Substantial damage. No injuries.*

The aircraft was approaching to land after a morning flight. There were a pilot and three passengers aboard the twin-engine aircraft.

The pilot had obtained destination airport weather information en route that reported wind from 280 to 300 degrees magnetic at 20 knots, gusting to 34 knots. He would be using runway 25. Approaching the airport, he attempted to contact the Unicom to determine weather conditions, but there was no operator available.

During final approach, the aircraft descended rapidly from a height of approximately 100 feet and struck the ground hard enough that the right main gear assembly broke away. The pilot elected to abort the landing and continue to his home base airport where better emergency and repair facilities were available. A short time after the aborted landing, the wind at the airport was reported to be gusting from 20 to 36 knots from the northwest.

After a flyby of the control tower at the home airport it was confirmed that the right gear was missing. The runway was foamed and the pilot accomplished a gear-up landing with no further difficulties. The aircraft sustained further damage due to the landing but the passengers deplaned with no injuries.

The pilot was cited for failing to adjust the airplane's approach speed for the gusty wind conditions at the airport where the gear had been damaged. He was familiar with the airport and the accident report stated that he should have been aware of a published cautionary warning that there was a possibility of windshear when landing on runway 25 with northwest winds in excess of 10 knots.

The windshear pilots are cautioned about is caused by buildings and farm silos near the threshold of the runway.

## Severe Icing Is a Severe Threat

*Beech 65 Queen Air: Aircraft destroyed. Fatal injuries to 1.*

The aircraft was carrying cargo across the southeast corner of Australia some time after 0300 hours in July, winter season down under. The area forecast included a freezing level at 4,500 feet east of an approaching front, moderate to severe icing in cumulus clouds, visibility less than four miles in heavy rain showers and less than 1,000 feet in snow showers.

After a normal departure, the pilot flew the aircraft to a cruising level of 8,000 feet. He reported passing his first checkpoint and was given further clearance. This was the last contact air traffic control personnel had with the pilot.

Persons sleeping in the path of the planned flight were awakened by very loud engine noises from an aircraft that was obviously flying at a very low altitude in an approximately southern direction. They saw a flash of light followed almost immediately by the sound of a thud.

The weather in the vicinity of the accident included snow and fog.

Several hours later, searchers found the wreckage of the aircraft; it had been destroyed and the pilot was fatally injured. The aircraft had struck power lines at a height of 100 feet and crashed. Weather in the area included snow and fog. Other pilots flying in the vicinity had reported encountering rime icing that sometimes was severe.

Other General Aviation

## Forced Landing Practice Taught Another Lesson

*Cessna 206: No damage. No injuries.*

The aircraft was being used for dual instruction. An instructor and a student were the only persons aboard the single-engine aircraft.

The maneuver was forced landing practice and, although the terrain was not suitable for an actual emergency landing, the instructor reduced power by pulling back the throttle and declared a simulated power failure. The student pilot accomplished the proper procedures and established a landing approach to a stretch of road. When the aircraft had descended to within a couple of hundred feet of trees, the instructor ordered the student pilot to add power and end the simulated forced landing approach. The student applied full power.

The engine did not respond.

The instructor checked the position of the fuel selector and called for the fuel boost pump to be activated, while watching an automobile moving in the section of road intended for the "simulated" forced landing. The engine started before an actual landing was necessary and the aircraft climbed back to altitude without further mishap. The flight was completed and neither pilot thought further about checking out the reason for the engine's failure to respond during the forced landing practice.

The aircraft sat for a week without being flown. During preflight engine runup prior to a long flight, the pilot advanced the throttle rapidly and the engine died. Remembering the practice forced landing episode, the pilot recalled previous trouble with the engine fuel pump. During an engine change 200 hours previously, the fuel pump had not responded well to pressure adjustment, and maintenance personnel had been having trouble adjusting the idle mixture recently. Further checking by the overhaul shop disclosed that the fuel pump's low-pressure adjustment screw was loose and it was not possible to maintain pressure adjustments; an excessive amount of adjusting had caused the screw to become loose.

Lessons learned included paying attention to signs that the engine was not functioning properly; that practice forced landings should be made where good approaches to actual landing sites are available in case the engine fails to respond; and that the engine should be cleared properly during idle descent to ensure its availability for the go-around.

## One Engine Out in Ice But no Emergency

*Piper PA-23-250 Aztec: Aircraft destroyed. Serious injuries to one, minor injuries to three.*

The pilot and three passengers were returning home from a skiing vacation in the light twin-engine aircraft.

After receiving a telephone weather briefing, the pilot filed an instrument flight rules (IFR) flight plan for 12,000 feet and, after ATC reported severe turbulence and heavy icing in the general area he requested a higher altitude. Cleared to 14,000 feet, the pilot remained in instrument meteorological conditions (IMC).

The pilot then requested a descent and was cleared to 10,000 feet even though severe turbulence and moderate to heavy icing was reported at that altitude. He reported that he was only experiencing light rime icing at the time.

During the descent, the VOR navigation reception from the station behind the aircraft was interrupted and the pilot was given radar vectors to help him stay on the airway until reliable VOR reception could be established from the station towards which he was headed.

The pilot reported continuous light rime icing and was cleared lower to 7,000 feet, the minimum radar vectoring level. Upon levelling off, however, the pilot requested a still-lower level but that was not available and ATC offered a vector to the south off the airway and toward lower terrain. The pilot declined the offer, and the controller questioned if the aircraft was picking up ice and whether the pilot could maintain his altitude. The pilot reported that the icing was light and that the flight was OK.

Within the minute, the pilot requested a lower altitude and was observed to have descended to 6,000 before the clearance was given two minutes later. The controller indicated there was an alternate airport eight miles away and asked if he could maintain that altitude, to which the pilot answered "yes."

Almost immediately, the pilot announced that he had an engine problem and could not maintain altitude. He requested a vector toward the alternate airport and advised that one engine was shut down. The aircraft disappeared from radar coverage and that was the last radio communication from the aircraft.

Subsequently, the aircraft entered heavy rain and showers of ice pellets as it descended beneath the clouds and, unable to maintain altitude, the pilot made a successful forced landing in rugged terrain. One passenger was injured seriously, and the other occupants sustained minor injuries, but they all were able to exit the aircraft before post-impact fire destroyed it.

At no point during the incident did the pilot declare an emergency to ATC.

The basic cause of the accident was that the pilot continued flight into severe icing conditions in an aircraft that was not properly equipped. Contributing factors were that he was advised of the severe icing by a previous flight along his route and that by not declaring an emergency, he precluded timely assistance.

## Dead Tree Snags Helicopter

*Bell 206B Jetranger III: Substantial damage. No injuries.*

The pilot was on the way from his home base to pick up a passenger at a small airstrip in a wooded area. Arriving at the destination, he overflew the landing site at a height of approximately 500 feet and began a wide, descending approach to a downwind leg.

While turning to base leg, the pilot heard a thump sound and noticed that both lower vision bubbles were broken. He assumed the helicopter had struck a bird and checked the engine instruments and caution lights but nothing was amiss, so he continued the landing.

After touching down, the pilot left the engine running while he inspected for damage. There was damage to the lower vertical tail fin but, with the tail rotor still turning, he did not inspect the area closely. He cancelled the passenger flight, and cleaned the cockpit area around the broken plexiglass, throwing out broken pieces of the canopy and some pieces of wood he assumed had blown in during the landing. Lifting off into a hover, the pilot checked that there were no unusual vibrations and flew back to home base.

Inspection by maintenance personnel after the aircraft had been shut down at the home facility revealed widespread damage to the main and tail rotor blades, dents and scrapes elsewhere on windshield and metal skin of the rotorcraft and a damaged antenna. There were no feathers or blood indicative of a bird strike; however, bits of wood and bark pointed to a tree strike.

A visit to the landing site revealed that the helicopter had collided with the top of a 150-foot-high dead tree approximately 250 feet away from the center of the landing strip. Although much taller than surrounding trees, the dead tree had no leaves to draw attention to it.

There were numerous contributing factors involved. The company was short of pilots and the workload was high; the pilot had worked a demanding 12-hour schedule the previous day. He had just returned to work from a holiday that involved visitors in the home and a sick wife, resulting in his having to assist with the children's schooling needs. The day of the tree strike, the pilot had begun work at 0545 and flew five attention-demanding flights; the accident flight was expected to be an easy one and he was relaxed. He made a wide left traffic pattern to give himself plenty of room for the approach, and in a helicopter that has a blind area on the lower left, failed to see the tree.

## Third Autorotation Was Not a Charm

*Bell 206B: Substantial damage. No injuries.*

The aircraft was being used for autorotation training. A flight instructor and a student pilot were the only occupants.

The student had successfully completed two autorotations to touchdown and was nearing the ground on a third simulated power-off approach. At a height of three feet, the student began applying cushioning collective pitch and leveled the rotorcraft. Then, when the aircraft was one foot above the ground, the student applied aft cyclic control, causing the rear portion of the landing skids to hit the ground. Both the instructor and the student applied forward cyclic control and the aircraft rocked back and forth through several cycles. By the time it came to rest, the helicopter had sustained substantial damage. The instructor and the student pilot were not injured. ♦