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Object Strikes, Complete Loss of Thrust Were Leading Causes of U.S. Turbine-engine Helicopter Tail-rotor Accidents, 1988 Through 1993

During the study period, 16 percent of U.S. civil turbine-engine helicopter accidents involved the tail-rotor system. Most tail-rotor accidents involved pilot errors, but complete-loss-of-thrust accidents were often attributed to maintenance deficiencies.

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All single-rotor helicopters require an antitorque device (usually a tail-rotor system) to counter the fuselage's reaction to the rotation of the main-rotor system. From 1988 through 1993, there were 74 U.S. civil turbine-engine helicopter accidents involving the helicopter's tail-rotor system, according to statistics from the U.S. National Transportation Safety Board (NTSB) and the U.S. Federal Aviation Administration (FAA) Accident/Incident Database (FAA A/ID). The data also indicated that:

- Fifty-eight of these accidents involved single-engine turbine helicopters;
- Sixteen involved multiengine turbine helicopters;
- Turbine helicopters flew an estimated 11.3 million flight hours during this period;
- The accident rate for U.S. turbine helicopters was 4.18 per 100,000 flight hours; and,
- The accident rate for U.S. turbine helicopters, in which the tail-rotor system was involved, was 0.65 per 100,000 flight hours.

Two commercially available alternatives to the tail rotor as an antitorque device are the NOTAR (No-Tail-Rotor) and the Fenestron system. The NOTAR, unique to some McDonnell Douglas Helicopter Systems aircraft, was not included in this study because it was not commercially available during the study period. The Fenestron system, unique to Eurocopter products, is a type of ducted fan that functions in place of a tail rotor. In this article, accidents involving Fenestron-equipped aircraft will be referred to as tail-rotor accidents.

Accidents involving the helicopter tail-rotor system can be divided into four categories:

- **LTE** (loss of tail-rotor effectiveness). These accidents are related directly to aerodynamics and normally do not result from a mechanical malfunction;
- **Strikes**. These are inadvertent tail-rotor strikes against objects, which typically result in loss of tail-rotor thrust;
- **CLT** (complete loss of thrust). These accidents are usually the result of a mechanical malfunction or failure of some part of the tail-rotor system; and,

- **Other**. These are events not described in the above categories.

Table 1 shows the number of tail-rotor accidents in each category, by year, within the study period. Figure 1 shows the 74 accidents divided among these four categories as percentages. Figure 2, page 3, shows the annual frequencies of tail-rotor accidents in the four categories during the study period.

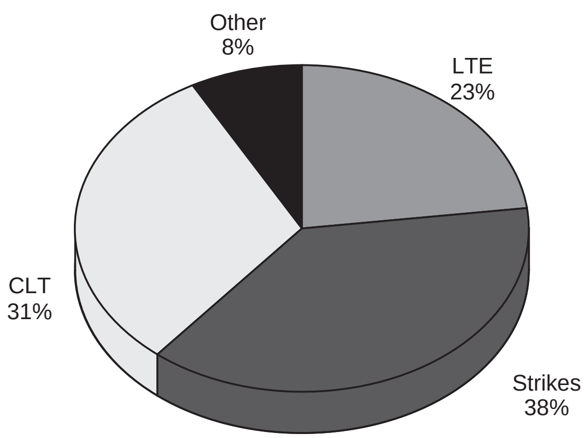
Table 1
Tail-rotor Accidents, by Category And Year, 1988–1993

Year	LTE	Strikes	CLT	Other	Total
1988	4	5	6	1	16
1989	4	6	6	1	17
1990	1	8	1	1	11
1991	3	3	6	2	14
1992	2	3	4	1	10
1993	3	3	0	0	6
Total	17	28	23	6	74

LTE = Loss of tail-rotor effectiveness
CLT = Complete loss of thrust

Source: Joel S. Harris

Tail-rotor Accidents, by Category, 1988–1993



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Source: Joel S. Harris

Figure 1

LTE. Seventeen of the 74 accidents involved LTE, a type of preventable accident that the NTSB attributes to pilot error. LTE accidents involve the inability of the helicopter tail rotor (or, in one accident, the Fenestron) to provide sufficient thrust to counter unanticipated yaw. LTE is not a result of mechanical failure or malfunction, but rather a combination of environmental conditions. It typically occurs at low airspeeds (less than 30 knots/26 miles per hour/42 kilometers per hour) and high power settings at high-density altitudes, and it can occur in any single-rotor helicopter. Only two of the 17 LTE accidents (11.8 percent) involved multiengine helicopters.

LTE results in "uncommanded right yaw rate (with a counter-clockwise-rotating main rotor) which does not subside of its own accord and which, if not corrected, can result in the loss of aircraft control," according to Bell Helicopters. Bell, however, warns that the term "loss of tail-rotor effectiveness" may be misleading and prefers to describe the events as "low-speed flight characteristics" that have been identified as contributing factors in unanticipated right yaw.

Bell recommends that if a sudden, unanticipated yaw occurs, the pilot should first use full opposite pedal while simultaneously moving the cyclic forward to increase speed. A reduction of collective pitch will help arrest the yaw rate, but "must be based on the pilot's assessment of the altitude available for recovery." If the spin cannot be stopped and ground contact is imminent, "an autorotation may be the best course of action."

A recovery technique for LTE was demonstrated in 1988 by a 3,558-hour airline transport pilot (ATP), although the pilot did not prevent an accident. Shortly after taking off on a sightseeing flight, the Bell 206B "began to spin to the right," according to the NTSB accident report. The pilot was unable to correct with opposite pedal. He "reduced the throttle and adjusted the collective," and the spin stopped. Nevertheless, the helicopter was low over the water. "A wave caught the skid and the helicopter entered the water ... ," the report said. The pilot suffered minor injuries, and the helicopter was destroyed. Postaccident inspection did not reveal any mechanical failure or malfunction.

In a 1989 LTE accident, a 4,700-hour ATP was operating an emergency medical service (EMS)-configured twin-turbine Aérospatiale AS355. The helicopter was on final approach to a short-takeoff-and-landing (STOL) airport located 7,073 feet (2,157 meters) above mean sea level (MSL), when the helicopter began to yaw to the left (the main rotor turns clockwise in the AS355).

"The pilot applied right pedal, but to no avail," the NTSB report said. "He lowered the nose to begin a go-around, but the yaw began to accelerate. The pilot then shut down both engines and made an autorotation." There were no injuries, but the aircraft sustained substantial damage. An investigation revealed no evidence of a tail-rotor drive malfunction or failure. The NTSB said that the probable cause of the accident was "loss of aircraft control during a slow-speed, downwind approach to a high-altitude" airport.

In a 1991 accident, a Bell 206 began losing airspeed after encountering deteriorating weather during an attempt to transit a "mountain saddle" in visual meteorological conditions

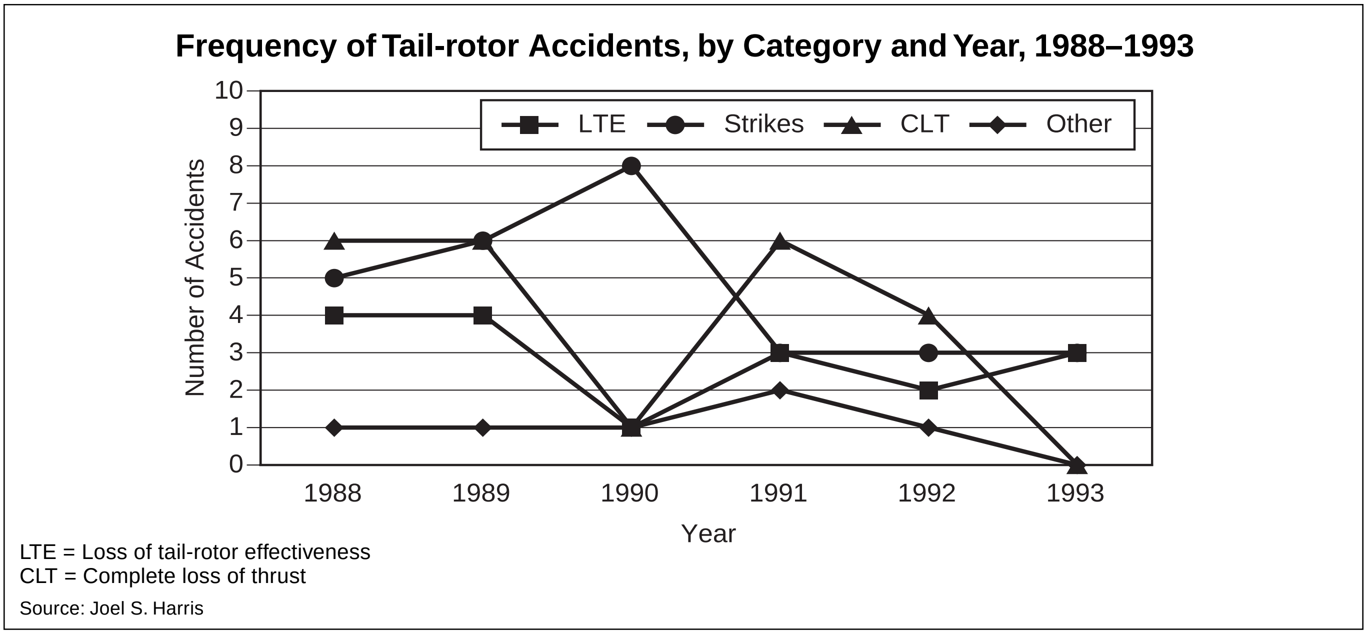


Figure 2

(VMC). As the aircraft slowed, it began to rotate to the right, the NTSB report said. The 1,600-hour commercial pilot said that she was unable to correct the increasing yaw rate with pedal input, and after the helicopter made three complete revolutions, the low-rotor-RPM horn sounded.

The pilot said that she elected to attempt a landing and lowered the collective. A hard landing followed, resulting in one serious injury, two minor injuries and substantial damage to the aircraft. The NTSB found no evidence of mechanical failure or malfunction.

Strikes. Twenty-eight of the 74 accidents involved the tail rotor striking an object, the largest accident category. In most of these accidents, the result of the strike was a loss of tail-rotor thrust.

In seven of the 28 strike accidents, the tail rotor struck the ground. Two of these strikes occurred during emergency landings for unrelated reasons. In one ground-strike accident in 1992, a 4,300-hour ATP landed a single-engine Hughes MD-500D on unstable terrain. "When he and the other front-seat passenger exited before the rear passengers, the helicopter rocked backwards, and the tail rotor struck the muskeg [mossy bog] while the main rotor was still turning," the NTSB accident report said.

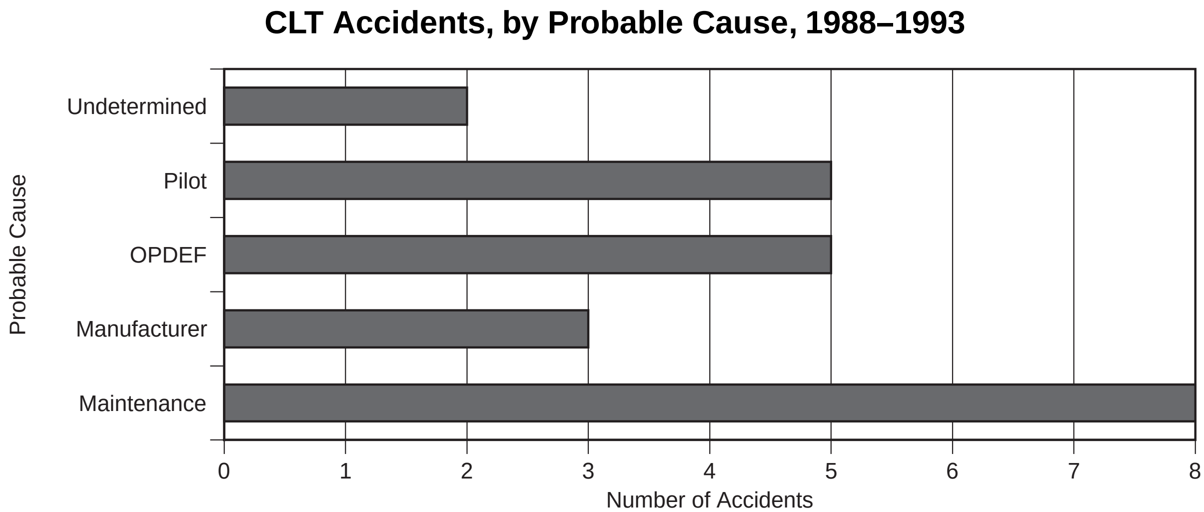
Following the strike, the pilot examined the drive train for damage and found none. He then elected to fly back to his base of operations. "During the flight the tail-rotor drive shaft separated, and [the aircraft] lost tail-rotor thrust," the NTSB said.

The pilot made an emergency water landing. There were no injuries, but the aircraft sustained substantial damage. According to the NTSB report, the pilot's company had an unwritten policy not to leave the helicopter until the blades completely stopped turning. The NTSB said that the probable causes of the accident included "procedures/directives not followed" by the pilot-in-command (PIC) and "inadequate [company] procedures/directives."

Five of the 28 tail-rotor strikes occurred during training or flight-proficiency checks. In one accident, a 10,000-hour ATP was making practice landings on an abandoned concrete building foundation in a twin-engine Aérospatiale AS355. "While at a hover after completing the landing, the pilot executed a 90-degree right-pedal turn, and the tail rotor struck a structural reinforcing bar that was protruding 18 inches [46 centimeters] out of the edge of the foundation," the NTSB report said. "Antitorque control was lost, and the aircraft spun 90 degrees before making a hard landing." There were no injuries, but the aircraft sustained substantial damage.

Although tail-rotor strike accidents were almost always preventable, pilot error was not cited as a probable cause in three of the accidents. These accidents involved passengers inadvertently walking into turning tail-rotor blades. In two accidents, the passengers were attempting to duck under the tail boom of the helicopter. In the only incident that involved a fatality, the NTSB report noted that the passenger "had been reminded at least three times that day to stay away from the rear of the helicopter."

In a 1988 accident where pilot error was cited as a contributing cause, a 2,500-hour commercial pilot brought an Aérospatiale AS350B to a hover in preparation for departure. The nose of the aircraft began to rise, according to the NTSB report. The pilot said that he could not control the aircraft, and "the aircraft began to descend and the tail rotor struck a security fence around the heliport," the NTSB said. The main rotor then struck a windsock pole. Both pilots sustained minor injuries, and the single-engine helicopter was substantially damaged.



CLT = Complete loss of thrust
OPDEF = Operational deficiency

Source: Joel S. Harris

Figure 3

A manufacturer's service bulletin was in effect providing for "protection against ice in the hydraulic servo by installation of protective covers." The protective covers had been installed on only two of the main-rotor servos but not the servo that controlled fore-and-aft cyclic control, according to the NTSB report. There had been freezing precipitation the night before the accident. In addition to inadequate maintenance, the NTSB said that "inadequate aircraft preflight" by the PIC was a probable cause of the accident.

Accident data from the study period showed that in addition to striking the ground, reinforcing bars, passengers and fences, tail rotors also struck wires, buildings, birds, trees and rocks.

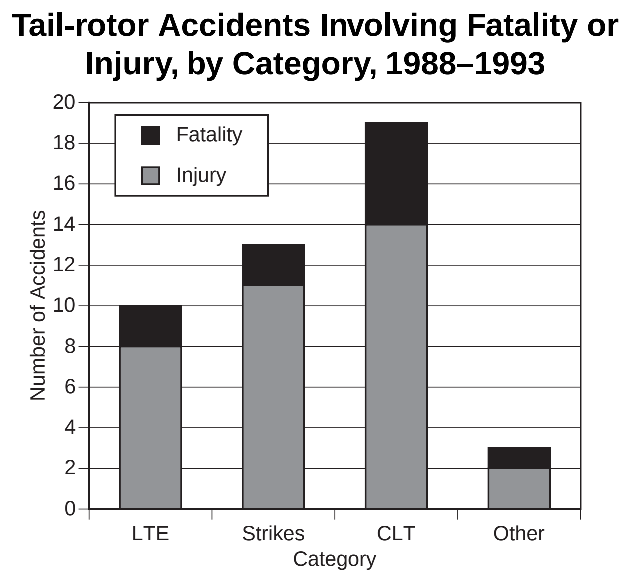
CLT. Twenty-three of the 74 tail-rotor accidents involved a complete loss of tail-rotor thrust that was not caused by a strike or LTE. CLT accidents usually involve mechanical failure of the tail-rotor drive system or one of its components. The NTSB attributed the majority of CLT accidents, unlike those in the other categories, to inadequate or improper maintenance that resulted in the failure of one of the tail-rotor components.

Table 2
Tail-rotor Accident Fatalities and Injuries, By Category, 1988–1993

	LTE	Strikes	CLT	Other	Total
Fatalities	5	2	17	1	25
Injuries	21	23	35	12	91
Total	26	26	52	13	116

LTE = Loss of tail-rotor effectiveness
CLT = Complete loss of thrust

Source: Joel S. Harris



LTE = Loss of tail-rotor effectiveness
CLT = Complete loss of thrust

Source: Joel S. Harris

Figure 4

Figure 3 shows CLT accidents grouped by probable cause. Operational deficiency (OPDEF), a term found in the FAA A/ID, indicates that neither the pilot, nor maintenance nor any other party was found to be at fault.

CLT accidents were also the most deadly, and were responsible for three times as many fatalities and twice as many total fatalities and injuries as any other category (Table 2).

Figure 4 shows the number of fatal accidents for each category and the number of accidents in which there was injury without fatalities. CLT exceeds all other categories.

Nine of 23 CLT accidents (nearly 40 percent) occurred during external-load operations such as long-line operations or aerial applications. An example of an accident involving external-load operations occurred when a 4,000-hour commercial pilot was hovering a Bell 204 at about 100 feet (30.5 meters) above ground level with a hopper extended from a cable.

"Witnesses heard a loud popping sound," the NTSB report said. "As they looked in the direction of the helicopter, they noticed the tail rotor was not turning and one blade appeared to be hanging. The pilot reported there was no warning of an impending antitorque problem when he lost control of the helicopter, which then collided with trees and crashed." The pilot was injured and the aircraft was damaged substantially.

An investigation revealed that the pilot had reported an oil leak from the 90-degree gearbox six days before the accident. The company mechanic subsequently replaced the gearbox, and a functional test flight was completed. The accident occurred after an additional six hours of operation.

A postaccident examination of the tail-rotor assembly revealed that one of the two retention bolts was missing from the tail-rotor pitch-change crosshead. The NTSB found that the tail-rotor hub pitch-change beam had not been safety-wired and said that the probable cause of the accident was improper maintenance.

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CLT was precipitated by external causes in at least four accidents. In one accident in 1992, a 6,070-hour commercial pilot's Sikorsky S-76 experienced a complete loss of thrust shortly after takeoff. The NTSB report said that "about one minute and 40 seconds after takeoff, the flight crew heard a noise, followed by loss of directional control."

An NTSB investigation found evidence that the engine cowling contacted the main rotor blades during the flight and then "made contact with section 2 of the tail-rotor driveshaft. Friction between the cowling and the driveshaft resulted in localized high temperatures and the tail-rotor shaft failed at that location."

The pilot performed an autorotation on very hilly terrain and the aircraft was destroyed. There were five serious injuries and one minor injury among the crew and passengers. The NTSB determined that the engine cowling had not been properly secured and cited the flight crew for "inadequate preflight inspection."

Another CLT accident occurred in 1991 during an attempt to attach a marker buoy to a downed helicopter that was floating inverted in the Gulf of Mexico. While the 12,000-hour commercial pilot hovered a single-engine Bell 206 over the downed aircraft, a crew member was lowered onto the downed aircraft by a nylon strap.

"As darkness set in, the crew [member] signaled to come back aboard," the NTSB report said. "The other observer threw the nylon strap to the crew [member] on the floating helicopter. The inboard end of the strap was attached to a seat belt anchor point. During the retrieval, the crew [member] released ... the strap and fell [100 feet] into the water. During the subsequent search, the crew [member] was found drowned. The pilot subsequently reported a low-fuel state … and returned [to shore].

"As he arrived over the beach, the pilot experienced a loss of directional control and autorotated to a hard landing. The nylon strap that had been left hanging outside the helicopter had become entangled around the tail rotor, shearing the drive shaft." The aircraft was substantially damaged. The NTSB said that "poor judgment by the pilot-in-command" was one of the probable causes of the accident.

Other. Six of the 74 accidents are described as "other."

- A single-engine Bell 206L-1 fell off an offshore platform in 1989 after the pilot attempted a precautionary landing because of yaw-control problems. The pilot had experienced left and right yaw and feedback through the pedals;

- An FAA inspector, while administering a check ride in 1990, simulated a fixed-tail-rotor failure by holding the right pedal slightly in, while the PIC removed his feet from the pedals. The PIC reduced the throttle to align the Bell 206 for landing, and a "firm" landing followed, wrinkling the tail boom and causing substantial damage to the helicopter;

- A loose cargo rope became wrapped around the tail-rotor pitch control of a Hughes 500 in 1991, causing the pilot to execute an autorotation;

- After a Bell 206 sustained a partial power loss in 1992, the pilot performed a successful autorotation to the water. He elected to maintain idle power after touchdown, and "wave action damaged the tail-rotor blades, which then made contact with the tail boom" and caused substantial damage to the aircraft;

- A misadjusted tail-rotor control system resulted in an uncontrolled collision with the water after takeoff. NTSB interviews revealed that the pilot did not stabilize the Aérospatiale 330J in a hover before initiating takeoff from an offshore platform. Because of the misadjusted tail-rotor control system, the helicopter began an uncommanded turn, and the pilot was not able to recover. There were one fatality and one serious injury, and the aircraft was destroyed; and,

- In 1991, the second-in-command of a twin-turbine S-76 "pulled the engine-speed levers" immediately after takeoff from an offshore platform, incorrectly believing that the aircraft was experiencing a tail-rotor failure. All 10 people on board were injured, and the aircraft was destroyed.

The likelihood that the pilot of a turbine-powered helicopter will experience an accident involving tail-rotor failure, malfunction or ineffectiveness is small. Nevertheless, data suggest that pilots can further reduce the risk of such an accident by:

- Knowing and understanding the effects of LTE and the particular susceptibility of the aircraft in the environment in which they operate;

- Making a thorough preflight inspection of the tail-rotor components, and ensuring that all required maintenance has been performed;

- Being aware and being cautious of all obstructions when operating an aircraft near the ground; and,

- Being thoroughly familiar with all tail-rotor emergency and malfunction procedures in the rotorcraft flight manual. Some emergencies involving the tail rotor require immediate action and may not allow the pilot time to find and use a checklist.♦

About the Author

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