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Fluid Leak Precipitates Fatal Crash in Experimental V-22 Osprey

The tilt-rotor aircraft underwent a series of emergencies in its final seconds of flight from which the crew could not recover. Under development as a multi-mission military aircraft, the V-22 has been touted as a likely urban civilian commuter.

by
Editorial Staff

The Bell Helicopter Textron/Boeing Helicopters V-22 Osprey tilt-rotor aircraft was being ferried to a military base in Quantico, Virginia, U.S., when it suddenly plunged into the Potomac River while on downwind for landing. The July 20, 1992, crash killed all seven crew members aboard. Autopsies of the victims determined that each individual on board the aircraft died of severe blunt-force injuries.

A U.S. Navy (Department of Defense) Court of Inquiry (COI) concluded that the aircraft "experienced multiple emergencies upon entering the downwind" and that "the primary cause of the mishap was a flammable fluid leak which was ingested by the right engine."

The report said the aircraft impacted the water at a descent rate of 6,300 feet (1,921 meters) per minute in a 14-degree nose-down pitch angle, with a longitudinal velocity of 85 knots and a lateral velocity of 60 knots. The impact energy was estimated to be 17 times greater than the ditching design condition. Impact forces were estimated to be about 79Gs, "well beyond the structural capabilities of the fuselage or human tolerance."

Four of the victims, including the pilot, were employed by the Boeing Helicopter Co. The copilot and two crew chiefs were members of the U.S. Marine Corps.

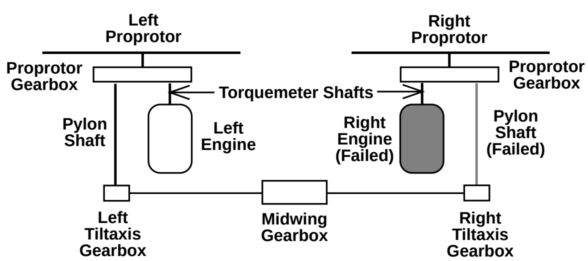
The COI said that while the crew complement of the accident aircraft could be justified, it "exceeded the mission essential minimum, which should be the guideline for crew size at this point in the test program."

The pilot-in-command of the V-22 (the project pilot), held an airline transport pilot certificate and was a certified flight instructor with multi-engine and instrument ratings. He had logged more than 6,000 total flight hours and was approved in 1990 as a V-22 instructor pilot. A graduate of the U. S. Naval Test Pilot School in 1981, he had flown on 42 of the accident aircraft's 93 flights, logging 31.9 flight hours as pilot-in-command and 12.4 flight hours as copilot. He had logged 44.3 hours of the accident aircraft's 104.4 flight hours. From March 1989 through July 1992, the pilot-in-command had logged 349.5 hours in the V-22 simulator and 155.2 hours in the V-22.

The copilot was also a graduate of the U.S. Naval Test Pilot School. He had accumulated a total of 3,727 flying hours, which included 61.5 hours of V-22 simulator time and 3.9 hours of V-22 flight time. He flew as copilot on three of the accident aircraft's 93 flights, including the accident flight.

The experimental aircraft was being ferried under visual flight rules (VFR) from Eglin Air Force Base in Florida to the U.S. Marine Corps base (MCB) at Quantico, where an official welcoming ceremony was scheduled. The purpose of the stop at Quantico was to conduct an egress demonstration and to show the aircraft to headquarters personnel.

V-22 Engine System



Source: U.S. Department of Defense

Figure 1

The COI report, obtained by the Flight Safety Foundation under provisions of the U.S. Freedom of Information Act, said the results of the crash investigation also identified human factors, maintenance and design issues.

The report said, "the Boeing organization at Eglin AFB [Air Force Base] from 18 to 20 July was inappropriately downsized, inadequately supervised and was too focused on the departure of both the team and the aircraft to ensure satisfactory completion of maintenance requirements."

The report also said, "There was tremendous pressure on [the pilot] to get the aircraft to Quantico at the proper time on Monday 20 July. The pressure was evident on Sunday afternoon in his mannerisms [to a coworker]. The scheduling of personnel also lent credence to the perceived pressure, since most Boeing personnel were scheduled to depart on the weekend with wives and families. In addition, there were banners at Marine Corps Headquarters announcing the arrival of the Osprey at Quantico at 1430 local time on 20 July." The aircraft left Eglin at 0955 and crashed at 1242.

Minutes prior to launch from Eglin, one of the flight test mechanics said that the V-22 seemed "to be pushing a lot of hydraulic fluid out of the Number Two side."

The COI said, "In the hurry to make the Quantico overhead time, auxiliary power unit (APU) problems encountered on turnup for launch [the start used the "emergency" APU setting] were not resolved prior to flight, creating uncertainty as to the ability to restart the aircraft following the planned en route crew switch and refueling at Charlotte (North Carolina)."

The preflight briefing, according to the COI, stated that there would be no attempt to fly non-stop from Eglin to Quantico.

The COI reported that during the flight, the pilot, after reviewing ground speed and fuel calculations, decided that a one-leg flight to Quantico was possible and should be attempted, otherwise "we'd never get out of Charlotte [because of APU and other problems]." The crew determined "that they would have 20 minutes of fuel remaining when they landed at Quantico" although the Boeing flight operations manual required "a minimum of 30 minutes fuel remaining upon landing."

At approximately 1016, the crew received the first of two cockpit warnings that required a return to base, but the crew concluded that a wiring problem was at fault and the pilot elected to continue the flight.

"Even when faced with a caution for which flight clearance specified 'land as soon as possible at the nearest suitable landing site,' onboard troubleshooting provided a plausible rational to continue," said the COI.

The report said the pilot "should have landed at the nearest suitable field as stated in the clearance. There were no provisions in the clearance for onboard troubleshooting.

"Continuing with the RTB [return to base] RTR [rotor] warning was significant, even if troubleshooting revealed that it might only be a wiring problem, because the presence of the RTB RTR warning made it impossible for other lower priority warnings to be displayed. Any real RTB RTR warning would not have been noticed, since the RTB RTR light was already on."

The report said that the anomalies did not cause the aircraft to crash.

The COI said Boeing and government management officials "placed undue pressure (real or implied) on [the pilot] and the Boeing Eglin detachment to get the aircraft to Quantico."

The report concluded: "The pilot submitted to the pressure to meet the MCB Quantico commitment and failed to act conservatively with his developmental aircraft."

According to the COI, during the downwind leg, at 120 knots and 1,300 feet (396 meters) above ground level, the Osprey's right engine surged "due to the ingestion of a flammable substance [probably proprotor gearbox oil] through the engine intake" following conversion from the airplane mode (0-degree nacelle angle) to 44-degrees nacelle angle.

The report added: "This first surge, which was accompanied by smoke and a flash, was controlled by the aircraft's governing system. The surge caused the torque command limiting system (TCLS) to disengage and the primary flight control system (PFCS) caution light to illuminate. Engine efficiency data shows that the right engine sustained damage during the first surge. Post-mishap inspection of the right engine revealed a 120-degree arc burned through the combuster casing, attributable to the presence of a flammable substance between the combuster liner and the diffuser case.

"Additional oil ingestion and small oscillations of the right engine persisted [probably unnoticed by the pilots] for several seconds until the pilots reset the PFCS, clearing the frozen TCLS input and causing a rapid power command increase to the engines. The right engine oversped, experienced two surges in quick succession, and then failed. The left engine oversped, as its power turbine did not declutch from the left proprotor system [which was driven to overspeed by the right engine through the interconnecting drive system]. Flashes of fire and smoke were associated with the surges.

"The left engine powered both proprotor systems for several seconds, until failure of the pylon drive shaft due to heat/fire in the right nacelle. Combined right pylon shaft/right engine failure resulted in loss of drive to the right proprotor system. Loss of lift/rapid rate of descent and significant left yaw followed. No indications of drive system failure were displayed in the cockpit, and the situation was further confused by a false warning of left engine failure."

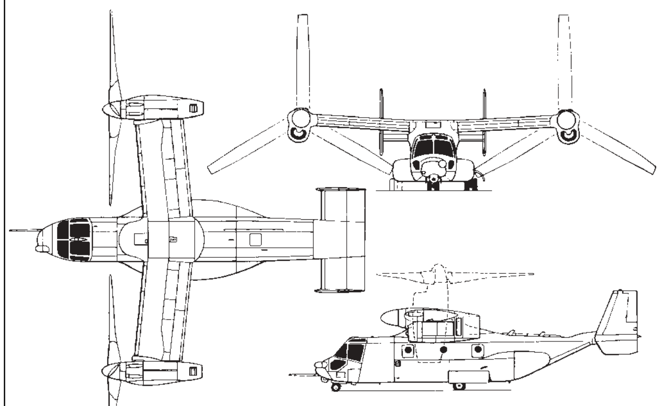
The uncommanded left yaw was due to the torque imbalance that was caused by high left proprotor speed and low right proprotor speed, the report said.

According to the report, the drive shaft failure caused a hydraulic leak and a flight control computer electrical failure that reduced flight control authority and prevented hydraulic control of the nacelles.

"Without hydraulic nacelle control there was virtually no chance of executing a successful/survivable ditching," the COI said.

The COI noted that the pilot (either intentionally or unintentionally) moved the thrust control level (TCL) full forward (maximum power) following indications of a dual engine failure. The report said that TCL design is similar to a (helicopter) collective, but operates in the opposite direction as a throttle (airplane). "Both military and contractor pilots have expressed concern that 'negative habit' transfer will result in incorrect TCL inputs by helicopter pilots, especially during emergency situations requiring instinctive response."

V-22 Osprey



The tilt-rotor program was initiated in 1982 as a U.S. Army program, and transferred to the U.S. Navy a year later. Bell is responsible for the wings, nacelles, rotor and transmission systems, and engine integration. Boeing's contribution is the fuselage, engine tail unit, landing gear, fairings and avionics integration.

Two Allison T406-AD-400 turboshaft engines power the V-22 at a takeoff rating of 6,150 shaft horsepower (shp) and maximum continuous rating of 5,890 shp.

Maximum vertical takeoff weight is 47,500 pounds (21,546 kilograms) and maximum standard takeoff weight is 55,000 pounds (24,948 kilograms).

Maximum cruising speed in helicopter mode is 100 knots and 275 knots in the airplane mode. The aircraft's service ceiling is 26,000 feet (7,930 meters) and has a range of 1,200 nautical miles (2,220 kilometers).

Source: Jane's All the World's Aircraft

A post-crash examination of the flight data indicated that 18 seconds elapsed between the onset of the first engine surge and the crash.

The COI said that the fluid leak into the right engine "may be attributable to maintenance error in installing an oil seal backwards on the torquemeter shaft." But the report added that it could not be conclusively determined that the reversed oil seal caused the leak, thus the possibility of other leaking seals or sources could not be ruled out.

In addition, the report said "ground testing with incorrectly installed seals did not show significant leakage, but a leak did occur on another V-22 with an incorrectly installed seal according to a government witness. Maintenance error cannot be assigned with certainty, but is considered to be a probable cause factor."

One member of the COI noted that the system used to conduct maintenance at Eglin "lacked organization, defined responsibilities and a formal reporting and documentation structure."

Secondary cause factors, the COI said, included:

- Ineffective quality assurance of the oil seal installation. The report added that procedures for the removal and replacement of the torquemeter seals contained in the technical manuals, blue prints and logistic support analysis manuals were vague and introduced the potential for incorrect installation;

- Inability of the engine inlet to withstand engine surge pressures;

- Accessibility of the engine intake to external flammable fluid sources, or "flaws in the design of the nacelle that allowed flammable liquid to accumulate in the engine inlet centerbody;"

- Analysis that led to the use of low-temperature composite material for the pylon drive shaft;

- Inadequate protection of the upper nacelle from heat/fire intrusion;

- Lack of adequate nacelle conversion redundancy; and,

- Failure of the warning system to adequately alert pilots to engine oscillations/surge and interconnecting drive system (ICDS) failure.

The report said "no design deficiencies were discovered which were uniquely tilt-rotor in nature," but suggested the following design changes:

- Drive shaft material change to improve heat tolerance;

- New torquemeter shaft oil seal design to prevent backwards installation;

- Improved engine firewall integrity;

- Engine inlet center body modification to preclude any chance of fluid pooling upstream of the engine and improved strength to accommodate engine surges without material failure;

- Additional cockpit display or other means of improving the display of warnings, cautions and advisories to the pilots;

- Improved failure detection and annunciation logic to preclude false warnings and to provide display of drive system failure; and,

- Software improvements to accommodate rate changes in various parameters without causing properly operating systems to be tripped off line (e.g. the TCLS).♦

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