Aviation Investigation Final Report

Location:	Peach Springs, Arizona	**Accident Number:**	WPR18MA087
Date & Time:	February 10, 2018, 17:19 Local	**Registration:**	N155GC
Aircraft:	Eurocopter EC130	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of control in flight	**Injuries:**	5 Fatal, 2 Serious
Flight Conducted Under:	Part 135: Air taxi & commuter - Non-scheduled - Sightseeing		

Analysis

The pilot of the helicopter was conducting his third air tour flight of the day, transporting six passengers to the operator's plateau landing site, known as Quartermaster, on the south bank of the Colorado River within the Grand Canyon. He was appropriately rated for this flight and was experienced executing approaches and landings at Quartermaster. Following an uneventful flight to the area, the pilot began a descent and approach from across the river to a ravine on the west side of the landing site. The accident helicopter was the ninth of ten helicopters scheduled to land at the site that afternoon, and because all of the pads on the east side of the site were occupied, the pilot initiated a descending left turn toward a landing pad located on the west side of the site, aligning the helicopter on an east-northeasterly heading. Photographs of the landing site windsock near the time of the accident indicated winds at magnitudes of 15 kts or greater from the north-northwest, resulting in tailwind conditions during approaches to the west pads. A pilot on the ground at the landing site reported that the accident helicopter began to decelerate as it approached the landing pads and entered a nose-up attitude, then turned left toward the landing pads, transitioned through several pitch oscillations, and drifted aft. The left turn continued through 720° of rotation before the helicopter descended into a canyon just west of the landing pads and impacted terrain. Photos indicated that the helicopter's final impact in the canyon was immediately followed by a postcrash fire. Postaccident examination of the helicopter and engine revealed no evidence of mechanical anomalies that would have precluded normal operation.

Two pilots who landed just before the accident conducted their approaches in a similar direction as the accident pilot and both later reported that they encountered adverse wind. The pilot who landed just before the accident reported that he encountered wind conditions that necessitated full right pedal and nearly resulted in a loss of yaw control. The accident helicopter's flight characteristics at the time of the accident would have included slowing airspeed, a high power setting, and a relative wind position that were all conducive to a loss of tail rotor effectiveness (LTE), thus it is likely that the loss of control was the direct result of LTE.

The landing site was located on a plateau and provided limited approach options due to its local topography. At the time of the accident, potential demarcation lines (boundaries of updrafts and downdrafts) would have been on the pinnacles of ridges located along the approach to the Quartermaster west pads. Figure 8 shows a conceptual illustration of potential demarcation lines and wind directions based on the terrain and wind environment present around the accident site at the accident time, and suggests areas where downdrafts, updrafts and turbulence could have impacted the accident flight's approach to the landing site.

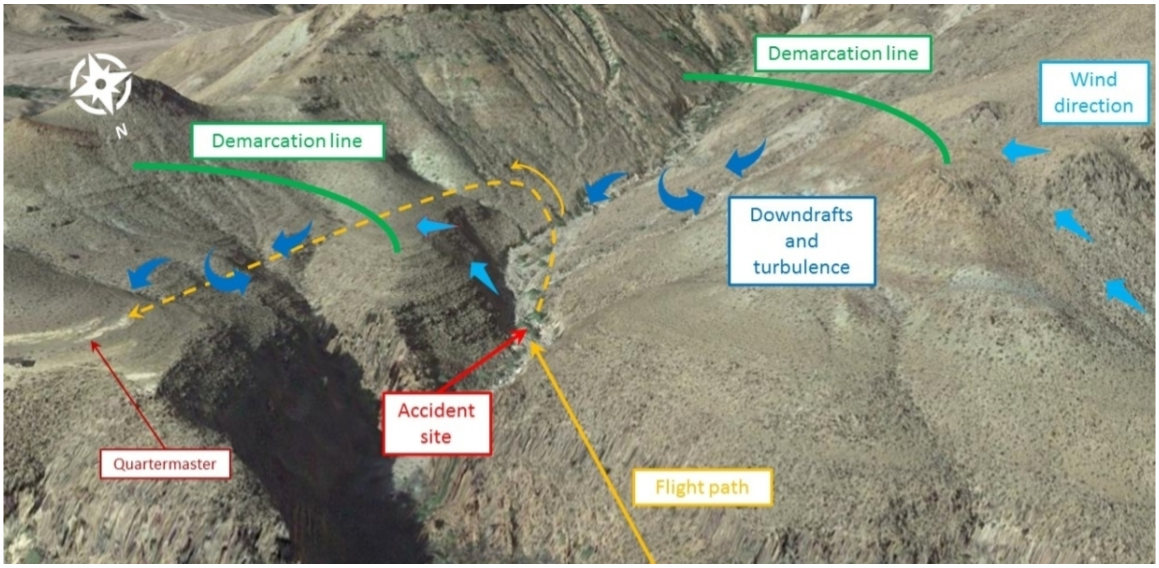

Figure 8. Conceptual display of demarcation lines at accident site

The proximity of other pilots and passengers who witnessed the accident resulted in an immediate response to aid the occupants of the helicopter; however, the remote location of the accident site and communication difficulties between on-scene and outside resources made rescue coordination challenging and victim transport by helicopter to the hospital did not begin until about 6 hours after the accident. Although all seven occupants survived the impact, they all sustained significant burn injuries, and three of the occupants were likely unable to egress the helicopter. The most significant factor affecting occupant survival was the immediate postcrash fire. The accident helicopter was not equipped, nor was it required to be equipped, with a crash-resistant fuel system. Due to a lack of data regarding the crash dynamics and impact forces, the effectiveness of such a system, if installed, in delaying the onset of a postcrash fire could not be determined.

The only source of local wind information at Quartermaster at the time of the accident was a windsock, which can only display wind speeds up to 15 kts. Further, windsocks cannot indicate the presence of downdrafts, turbulence, or any other local environmental conditions that may affect flight safety, particularly when landing in a confined area.

The operator provided its pilots with a morning weather briefing on the day of the accident, which advised of gusty wind conditions in the area of the accident site forecast to increase throughout the afternoon. Weather advisories issued after the morning weather briefing, several hours before the accident, indicated a cold front proceeding through the area of the accident site with associated wind gusts and turbulence. This information was likely not captured by the operator and distributed to its pilots even though some of the forecasts included wind conditions above the maximum wind outlined in the company's general operations manual (GOM). Because there was no additional wind information at the landing site beyond the windsock, it could not be determined the actual wind conditions at the landing site at the time of the accident; however, pilots who landed before the accident pilot estimated the wind to be 15 to 20 knots, which is below that specified in the GOM. Although the morning briefing was not intended to be the pilots' sole source of weather information, it was likely the primary weather information the accident pilot received before the accident, as he had recently flown to Quartermaster and is not likely to have rechecked the weather.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

A loss of tail rotor effectiveness, the pilot’s subsequent loss of helicopter control, and collision with terrain during an approach to land in gusting, tailwind conditions in an area of potential downdrafts and turbulence.

Findings

Aircraft	Prop/rotor parameters - Capability exceeded
Aircraft	Yaw control - Not attained/maintained
Environmental issues	Tailwind - Effect on operation
Personnel issues	Aircraft control - Pilot

Factual Information

History of Flight

Approach	Other weather encounter
Approach	Loss of control in flight (Defining event)
Uncontrolled descent	Collision with terr/obj (non-CFIT)
Post-impact	Fire/smoke (post-impact)

HISTORY OF FLIGHT

On February 10, 2018, about 1719 mountain standard time (mst), an Airbus Helicopters EC130 B4 helicopter, N155GC, was destroyed when it was involved in an accident near Peach Springs, Arizona. The pilot and one passenger sustained serious injuries, and five passengers were fatally injured. The helicopter was operated as a Title 14 *Code of Federal Regulations (CFR)* Part 136 air tour flight.

On the day of the accident, the pilot performed a canyon landing, and an air tour flight before the accident flight. All of the day's flights departed Boulder City Municipal Airport (BVU), Boulder City, Nevada. Both the second flight and the accident flight had a destination of Quartermaster, an unimproved landing site regularly used by the operator within the Grand Canyon's Quartermaster Canyon. The pilot's second flight of the day took place in the early afternoon and returned at 1455. The accident flight departed at 1642.

The accident helicopter reached the Hoover Dam about 1652 and entered the Grand Canyon West Special Flight Rules Area 50-2 about 1713, where the pilot flew the standard helicopter route known as the "Green 4 route." The last radar return was captured at 1717 and depicted the helicopter about 3.5 nautical miles (nm) west of the accident site, consistent with a descent into the canyon to Quartermaster.

The accident helicopter was one of ten helicopters scheduled to land at the site on the afternoon of the accident. The tour operation intended for the ten helicopters to sequentially land at Quartermaster and allowed for them all to be present at the landing site at the same time. The accident pilot stated that, during the approach to Quartermaster, he noted that the eight helicopters that had already landed were facing in different directions, indicating variable wind conditions. The combination of the windsock direction, orientations of the parked helicopters, and unoccupied landing pads on the west side of the landing area prompted the pilot to conduct an approach from the west and touch down on one of the west landing pads. He recalled that the two helicopters that landed immediately before him were on the west landing pads facing east, the same as his chosen approach direction, and noted that the windsock indicated wind from the north/northeast.

The pilot stated that he normally remained on the north side of the Colorado River, crossing the river between 200 and 300 ft above ground level (agl) while approaching Quartermaster for landing. After crossing the river, he entered a left turning descent toward the landing area. (See figure 1.) He stated that, as he made the left turn, the helicopter encountered what he described as a “violent gust of wind” and began to spin, and as a result he was unable to maintain directional control.

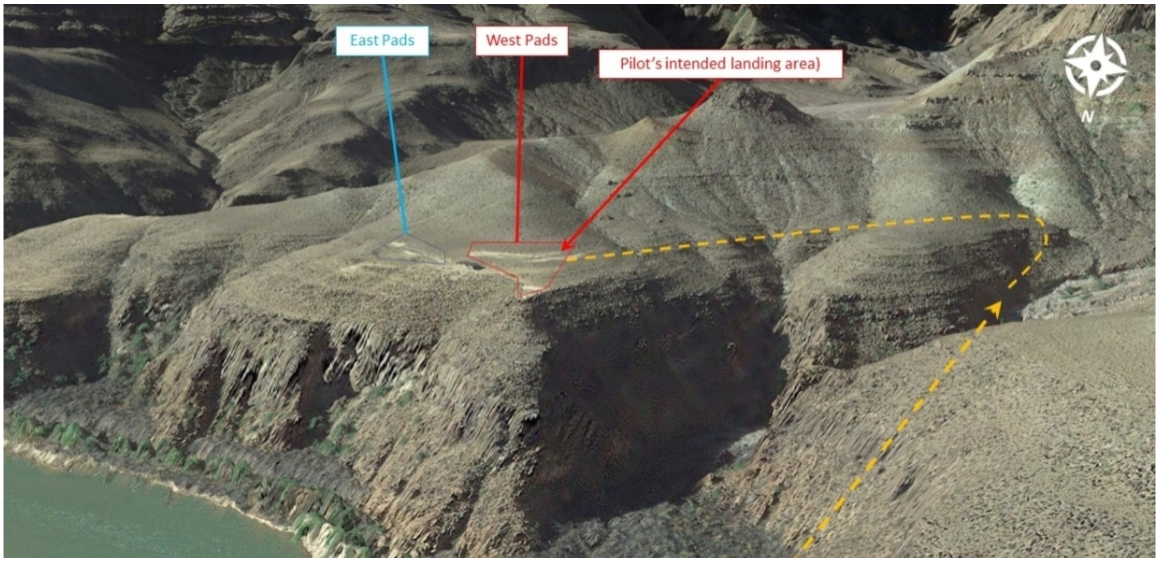

Figure 1. Graphical representation of typical approach to west pads

A Papillon pilot on the ground at Quartermaster watched the accident helicopter as it approached from across the river and assumed that the pilot planned to land on the west pads based on his approach path. He reported that the helicopter decelerated and then entered an approximate 15° nose-up pitch attitude. While maintaining altitude, the helicopter began a left turn toward the landing site. According to the witness, during the turn, the helicopter transitioned into a level attitude, followed by a nose-low attitude. He further reported that the helicopter began to drift aft as the left turn continued and returned to a level attitude before it rotated 360° and began a descent. After a second 360° rotation, the helicopter collided with terrain. A postimpact fire ensued.

Previous Approach and Landings at Quartermaster

The first five helicopters to land at Quartermaster on the afternoon of the accident approached from the east and landed on the east pads, facing west. The next three helicopters landed on the west pads and used a similar approach as the accident helicopter. The tenth helicopter did not land due to the accident.

PERSONNEL INFORMATION

The pilot began his employment as a full-time pilot with Papillon Airways on June 3, 2013 and was trained by Papillon in the accident helicopter make and model. In 2014, the pilot transitioned into a role as a part-time pilot to pursue another career opportunity. At the time of the accident, the pilot’s primary occupation was in a different field (not as a pilot), but he continued flying for Papillon in a part-time capacity.

Company training records revealed that the pilot’s most recent line check in accordance with 14 *CFR* Part 135 was accomplished in December 2017 and showed satisfactory grades for all areas of the examination; however, the lead pilot who conducted a portion of the pilot's training in preparation for this line check reported that he had marked the pilot's performance "unsatisfactory." Specifically, he noted that the pilot had experienced difficulty maneuvering the helicopter during high wind conditions and did not have enough altitude as he turned during 180° autorotations. The pilot passed his check ride with another lead pilot 1-2 days later.

According to the operator, at the time of the accident, the pilot had flown passengers into the Grand Canyon for them a total of 836 times, with 581 landings at Quartermaster. The pilot stated that he felt comfortable flying the Airbus Helicopters (formerly Eurocopter) EC130 B4 helicopter and landing at Quartermaster.

Prior to becoming an air tour pilot for Papillon, the pilot flew air tours in non-turbine powered helicopters in the Midwestern United States.

HELICOPTER INFORMATION

Fuel System Crash Resistance

On October 3, 1994, the FAA introduced improved fuel system crash resistance standards for newly-certified normal category helicopters. These standards, outlined in 14 *CFR* 27.952, are intended to minimize fuel spillage near ignition sources to improve the evacuation time needed for crew and passengers to escape a postcrash fire; however, they were not retroactively applicable to either existing helicopters or newly-manufactured helicopters whose certification and approval predated the revised standards.

The accident helicopter, manufactured in 2010, was not equipped, nor was it required to be equipped, with a fuel system meeting the contemporary fuel system crash resistance standards. An option to retrofit the EC130 B4 with a crash-resistant fuel system was approved by the FAA in December 2017. According to the operator, the retrofit kits were not available to them until April 2018, after which they completed a retrofit of their existing fleet of EC130 B4 and AS350-series helicopters by August 2018. Airbus Helicopters issued Safety Information Notice 3281-S-28 on November 5, 2018, which recommended that operators of the EC-130 and AS350 helicopters retrofit them with 14 *CFR* 27.852 compliant crash resistance fuel systems.

In July 2015, the NTSB issued Safety Recommendation A-15-12, which recommended that the Federal Aviation Administration (FAA) require the implementation of crash-resistant fuel system airworthiness standards for all newly manufactured rotorcraft, regardless of the original certification date, to reduce the risk of a postcrash fire in survivable accidents involving these rotorcraft. Section 317 of the FAA Reauthorization Act of 2018 prohibits helicopters manufactured after April 5, 2020, from flying in US airspace unless certified with a crash-resistant fuel system. Pending further information on the FAA's efforts to address this issue with rulemaking, the NTSB had classified A-15-12 as "Open – Acceptable Response."

METEOROLOGICAL INFORMATION

Surface Observations

The automated observation at Grand Canyon West Airport (1G4), located at an elevation of 4,816 ft mean sea level (msl) about 2.6 nm northwest of the accident site, recorded wind from 330° at 15 knots (kts) with gusts to 19 kts at 1705. At 1725, the station recorded wind from 330° at 16 kts with gusts to 22 kts.

Papillon and another helicopter operator each owned a weather station about 2 miles north-northwest of the accident site, at elevations about 1,200 ft msl. At 1700, the Papillon station reported wind from the north-northwest at 11 kts; at 1710, the wind was from the north-northwest at 11 kts gusting to 19 kts. At 1720, the wind was from the north at 11 kts, and at 1730, the wind was from the north-northwest at 12 kts, gusting to 24 kts. (The wind was recorded in miles per hour; the data has been converted to kts in this report.)

The other station recorded a north-northwest wind at 10 kts gusting to 19 kts at 1700. The following three observations, recorded at 10-minute intervals, indicated northwest/north-northwest wind at 10 to 11 kts.

Quartermaster was equipped with a windsock that was located near the landing pads. A photo of the windsock taken about 1713 showed the windsock in its fully extended position, consistent with a wind velocity of 15 kts or greater. (See figure 2.)

Figure 2. Photograph taken at 1713 MST of windsock at Quartermaster

Papillion Pilots' Recollections of Wind Conditions at Quartermaster

One pilot, who entered the canyon about 1646 and landed second in the sequence, encountered what he estimated to be a 20-kt headwind from the west while approaching an east pad. Another pilot, who entered the canyon about 1704 and landed fifth in the sequence, reported a northwest wind while landing on an east pad. He reported that he warned other pilots over the company radio frequency of a tailwind during the approach; however, only the sixth pilot to land recalled hearing this transmission.

The pilot of the sixth helicopter to land, who entered the canyon about 1708, estimated variable winds between 15 and 20 kts.

The seventh pilot to land entered the canyon at 1709. During his approach to the west pads, his intended destination, he recalled that the helicopter's tail swung rapidly due to strong winds and he applied significant right pedal and crabbed the helicopter to maintain the approach.

The last helicopter to land before the accident entered the canyon at 1710 and touched down about 2 minutes before the accident occurred. The pilot had experience flying in mountainous terrain, knew of the presence of 15-20 kt winds from the east, and thus anticipated windshear during the approach. While turning toward the west pads, he experienced a strong wind that swung the nose of the helicopter about 90° to the left. The airspeed rapidly decayed and it required all of his effort to maintain control of the helicopter. As the helicopter began to descend, he increased collective to arrest the descent and was able to maintain control by pushing the cyclic forward and right to increase airspeed while applying full right pedal to keep the nose straight. He successfully landed the helicopter on one of the west pads.

The accident pilot reported that he tried to be conscious of the wind during previous flights into Quartermaster and added that he had never experienced a violent wind shift like the one he encountered on the day of the accident. When discussing making the final turn to approach into Quartermaster, the accident pilot stated that “ninety percent of days are…it’s calm and you don’t think twice.”

Weather Synopsis

A National Weather Service (NWS) Surface Analysis Chart for 1400 showed a low-pressure center along the Utah/New Mexico Border. A cold front extended west from this low-pressure center, and the accident site was located just ahead of the front. In a subsequent Surface Analysis Chart issued at 1700, the cold front had moved south of the accident site into north-central Arizona. Clear skies were reported across the region except in far northern Arizona and southern Utah, which indicated overcast sky conditions.

The NWS sustained wind speeds for the accident region showed forecasts for increasing wind speeds throughout the day.

Upper Air Data

A high-resolution rapid refresh model sounding valid for the accident location at 1700 was retrieved from the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory. The surface elevation of this model was run at 1,863 ft, about 400 ft higher than the terrain elevation of Quartermaster. The model showed wind from the north-northwest at speeds between 10 kts near the surface to about 20 kts near about 5,000 ft. Sounding calculations showed low-level wind shear near the surface.

Weather Forecasts

An Area Forecast Discussion (AFD) issued at 1637 reported a strong cold front and widespread wind gusts during the evening on the day of the accident. A previous AFD forecast a strong cold front to move through the region that afternoon and evening, with winds from the north to northeast at sustained magnitudes from 20-30 kts and gusts between 40-50 kts.

An urgent Weather Message was issued by the NWS at 1008 effective for the accident site at 1800. The Weather Message referenced an NWS wind advisory, which indicated that wind would increase in the late afternoon, peak overnight, and decrease through the following morning. The wind was forecast to be 20-30 mph sustained with gusts of 30-45 mph and possible isolated gusts to 55 mph.

A Graphical Forecast for Aviation was issued about 1500 and valid for 1700 that depicted clear sky conditions, a surface visibility of greater than 5 statute miles, and northwesterly surface wind gusts between 20 and 35 kts in the accident region.

The closest Center Weather Service Unit issued a Meteorological Impact Statement at 1545 to expect gusty westerly wind of 25 to 35 kts gusting to 40 to 45 kts over the mountains and deserts on the afternoon and evening of the accident in the area of the accident site.

Operator's Weather Procedures

According to Papillon's General Operations Manual (GOM), "For flights conducted within the Local Tour Area, the Director of Operations (DO), Chief Pilot, Director of Utility Operations, or a Management Designee will determine the weather based on information obtained from an approved source." Further, the GOM stated that pilot weather briefings are conducted as part of a daily morning safety briefing and the weather information would be posted on the bulletin board of the pilot break room. These briefings must include adverse weather advisories (SIGMET/AIRMET), current weather (METARs), terminal forecasts (TAF), area forecast, winds and temperatures, pilot reports and NOTAMS, if applicable. According to the DO, the morning briefings were conducted by a lead pilot and occurred about 0545. The accident pilot's shift started about 4 hours after the morning weather briefing; however, he initialed the briefing sheet to indicate that he had reviewed the provided weather information.

The operator's daily weather briefing was a company-produced document that included current weather conditions, TAFs, area forecasts, NOTAMs, and AIRMETS/SIGMETS/PIREPS/TFRs. The briefing sheet for the day of the accident showed wind at 7 knots at 1G4. The area forecast portion of the briefing sheet included a synopsis that gusty winds from the north would spread southward and would be accompanied by a cold front but did not offer any further wind information. The briefing sheet also presented three NOTAMs, two AIRMETs, and the TAF for McCarran International Airport (LAS), Las Vegas, Nevada, which did not show any forecast weather events or wind conditions for Quartermaster.

In addition to the weather briefing, the operator had a pilot's station in the passenger building where pilots could access additional weather information, and their lead pilot monitored PIREPs and aviation weather data throughout the day. The company's control tower staff could also relay weather information to the lead pilot, although this was not a required part of their duties. Interviews with several

Papillon pilots revealed that the primary means of assessing the weather conditions before a flight included reports from pilots returning from the Grand Canyon and wind indicators near Quartermaster, the windsock at Quartermaster, and a weather station about 2 nm away. Several pilots stated that they would talk to other pilots at the terminal after returning from Quartermaster to advise them about the current wind conditions. The more senior pilots stated that they would make radio transmissions regarding the wind if they found it particularly surprising or challenging. One pilot stated they were cautious of making more radio transmissions than necessary to avoid frequency congestion given that other companies also operated in the area. The operator did not require its pilots to communicate wind information over the radio, but did discourage unnecessary radio communication and encouraged pilots to report "safety of flight" matters such as pilot reports on the company radio frequency. Multiple Papillon pilots stated that the winds at Quartermaster were unpredictable and that the wind direction could drastically change during an approach into the landing site.

The accident pilot was unable to recount how he assessed the weather conditions on the day of the accident, but described how he normally obtained weather information before a flight. He stated that he would not recheck the weather between tour flights into the Grand Canyon because there was only a short turnover between flights and because he had recently been to the destination. He stated that pilots returning from Quartermaster would relay wind information when they arrived back at the terminal. Upon arriving at Quartermaster, the pilot would typically use a nearby windsock, Quartermaster's windsock, and the directions of parked helicopters to discern the direction of the wind.

APPROACH AND LANDING SITE INFORMATION

Quartermaster Elevation and Topography

Quartermaster was a landing site located on the south side of the Colorado River in the Grand Canyon, about 53 nm east of BVU. The site was in an arid region on a plateau approximately 3,300 ft below the rim of the Grand Canyon at an elevation of 1,450 ft msl. Quartermaster's 600-ft-long by 150-ft-wide landing area comprised packed dirt/rock and loose rock, with sparse, low vegetation. A March 2017 written agreement between the Hualapai Sovereign Nation and Papillon authorized Papillon to use the 10 available landing pads and defined the number of landings allotted per year.

Title 14 *CFR* Part 95.15 used the geographic coordinated system to define sections of the Western United States as "mountainous areas." The coordinates referenced in the regulation included the Grand Canyon under this definition.

According to Papillon, the number of passengers the company flew into Quartermaster increased annually from 11,305 in 1999 (2 years after they started offering air tours to Quartermaster) to 77,742 total passengers the year before the accident. From the start of the operator's service into Quartermaster to 2017, they had flown 1,028,623 passengers into Quartermaster, landing 179.661 times without any accidents.

The operator did not issue any written guidance to its pilots regarding specific approaches, approach profiles, or landing pads to use under certain conditions. According to the operator's chief pilot, they were unable to predict which pad/approach would be favorable. He noted that their pilots were trained to conduct approaches into the wind, but were also professional pilots who, under 14 *CFR* 91.3, are directly responsible for and are the final authority as to the conduct of the flight.

Papillon pilots typically used two main approaches into Quartermaster; the "downriver landing" (used when landing on the east pads) and the "upriver landing" (used when landing on the west pads). According to the operator, these approaches were established by pilots and management when they began service into Quartermaster in 1997. Both approaches began from the north side of the Colorado River. The downriver landing required the pilot to cross the river west of Quartermaster and overfly a saddle-shaped landmark referred to as the “notch,” located south of the landing site. The pilot then performed a descending left turn to the east side of Quartermaster, touching down facing west-northwest.

Quartermaster is part of the Hualapai Sovereign Nation and its use is controlled through an agreement with the operator. The agreement prohibits the fixed marking of any touchdown and lift off zones, or any fixed means for delineating preferred landing pads or maneuvering areas. Landing pads were selected by each pilot upon arrival based on availability and wind direction. The first pilots to arrive in a group typically landed on the pads closest to the center of the landing area.

WRECKAGE AND IMPACT INFORMATION

The helicopter came to rest upright in rocky terrain about 300 ft below the landing site on a heading of 222° magnetic. Most of the wreckage was consumed by the postcrash fire except for the tail boom and fenestron, which had separated from but were collocated with the fuselage. (See figure 3.) The engine, still attached to the engine deck, was found in the main wreckage and sustained fire damage. All three main rotor blades remained attached to the main rotor hub and exhibited damage consistent with high rotational energy. The tail stinger, fenestron hub cover, a toe from a skid step, and small pieces of transparent windshield were found on a canyon slope east of the main wreckage.

Figure 3. Photograph of accident site

Airframe Examination

Continuity of the flight control system and main rotor drive system could not be determined due to postimpact fire damage.

The fenestron remained attached to the tail boom, which was found adjacent to the cockpit. Circular impact signatures were observed on the tail rotor drive shaft cover, consistent with the tail rotor drive shaft rotating at impact.

All three main rotor blades were found at the main wreckage site and remained attached to their root ends at their respective main rotor blade sleeves, which were attached to the Starflex. All three pitch horns remained attached to their respective sleeves and all three Starflex arms were fractured.

All three main rotor servo controls remained installed. Two of the three pitch change links were found in their normal positions attached to their respective pitch horns and rotating swashplate attachment points, but their link body was fractured. A portion of the third pitch change link body was found near its normally-installed location.

The fenestron control cable was fractured near the tail boom separation. Continuity of the control cable was traced from a fracture at its forward end to the fenestron blades. The fracture surface exhibited signatures consistent with overstress failure. A forward portion of the fenestron control cable was observed in the main wreckage; however, control continuity could not be established due to thermal damage.

Most of the fenestron blades remained attached to the hub, with the exception of one blade, which was fractured at its root; the blade was found on the ground immediately below the fenestron. The fenestron drive shaft did not exhibit anomalous damage and the external splines on the forward end of the drive shaft did not exhibit any anomalous wear.

Engine Examination

Examination of the reduction gearbox revealed signatures consistent with engine operation at the time of impact. The power turbine blades did not display evidence of blade shedding and the magnetic plugs showed no evidence of debris.

MEDICAL AND PATHOLOGICAL INFORMATION

Toxicology tests performed by the FAA's Forensic Sciences Laboratory on specimens from the pilot were negative for all tested-for drugs except those used during medical treatment following the accident.

SURVIVAL ASPECTS

Seats

The helicopter was equipped with 8 single-occupant energy attenuating seats manufactured by Zodiac Seats, designed and certified to the standards contained in EASA ETSO C127a. (See figure 4.) All of the seats were destroyed by postcrash fire. Each of the eight seats was equipped with a 4-point rotary buckle restraint, all of which were recovered from the accident site.

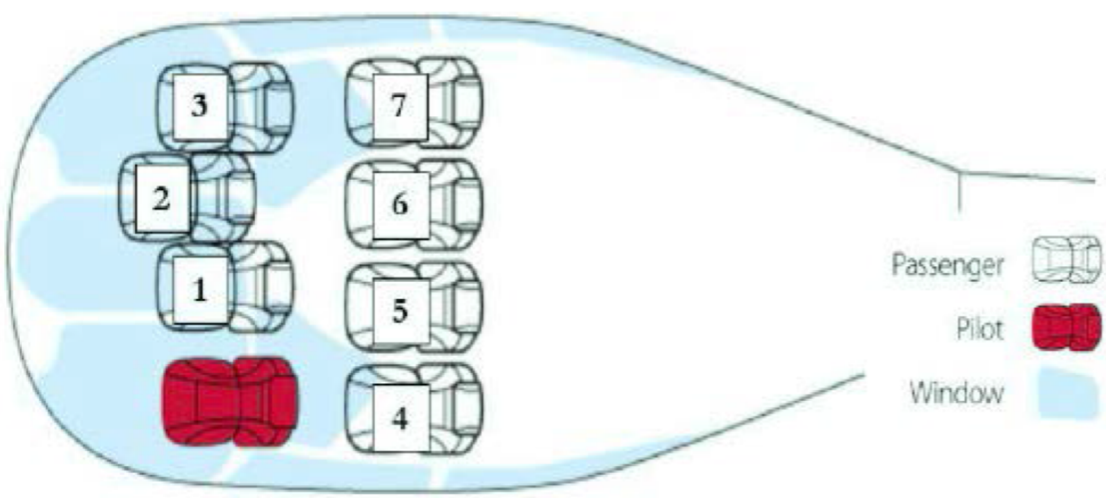

Figure 4: Accident Helicopter Seat Configuration

The fire extinguisher was normally stowed in a bracket on the floor between the pilot seat and passenger seat No. 1. The fire extinguisher was charred and found in the wreckage. Seat no. 1 was unoccupied.

Injuries

Passengers in seat Nos. 2, 6, and 7 did not have either the ability or opportunity to evacuate and died due to burns and smoke inhalation injuries; no blunt force traumatic injuries were noted by the medical examiner.

The pilot and passengers in seat Nos. 3, 4, and 5 sustained serious thermal injuries. Passengers in seat Nos. 3 and 4 succumbed to their burn injuries several days after the accident. In addition to their thermal injuries, the passenger in seat No. 5 sustained a spinal fracture. The pilot sustained an open left leg fracture.

Emergency Response

A photograph of the accident site taken at 1718:49 (after the accident) by a witness in an inbound helicopter showed white smoke and/or dust in the area of the accident site, while a second photograph taken about 7 seconds later showed flames and black smoke.

Numerous individuals, including pilots and passengers from other helicopters, were at Quartermaster at the time of the accident. Several Papillon pilots and members of the Royal Australian Air Force (RAAF) retrieved first aid kits from other helicopters and responded to the accident site, arriving about 20 minutes after the accident. They observed the burning helicopter and the pilot and three seriously injured passengers who were outside the helicopter. (See figure 5.)

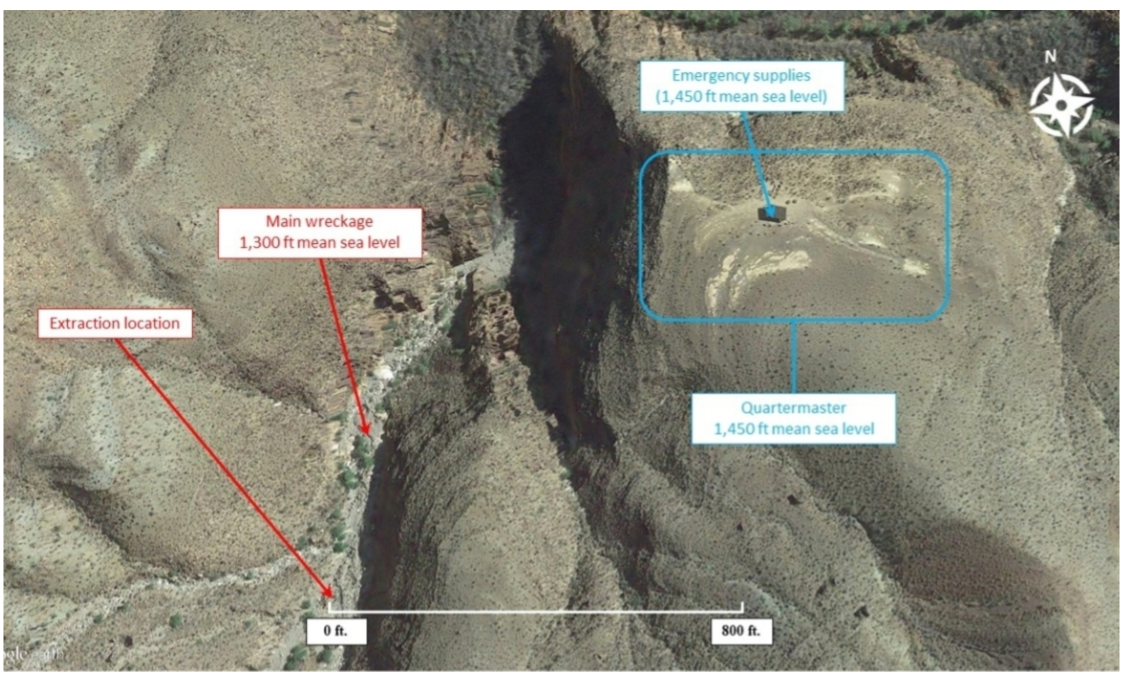

Figure 5. Quartermaster landing zone, accident site, and extraction location

The helicopter was equipped with an Artex C406-N HM emergency locator transmitter (ELT), which transmitted an alert notification and location information to the Air Force Rescue Coordination Center (AFRCC) at 1719:42.

The location of the accident site posed significant challenges and extended the response time for emergency personnel, who had to be flown in by helicopter. (See figure 6.) These first responders reached the accident site about 45 minutes after the accident.

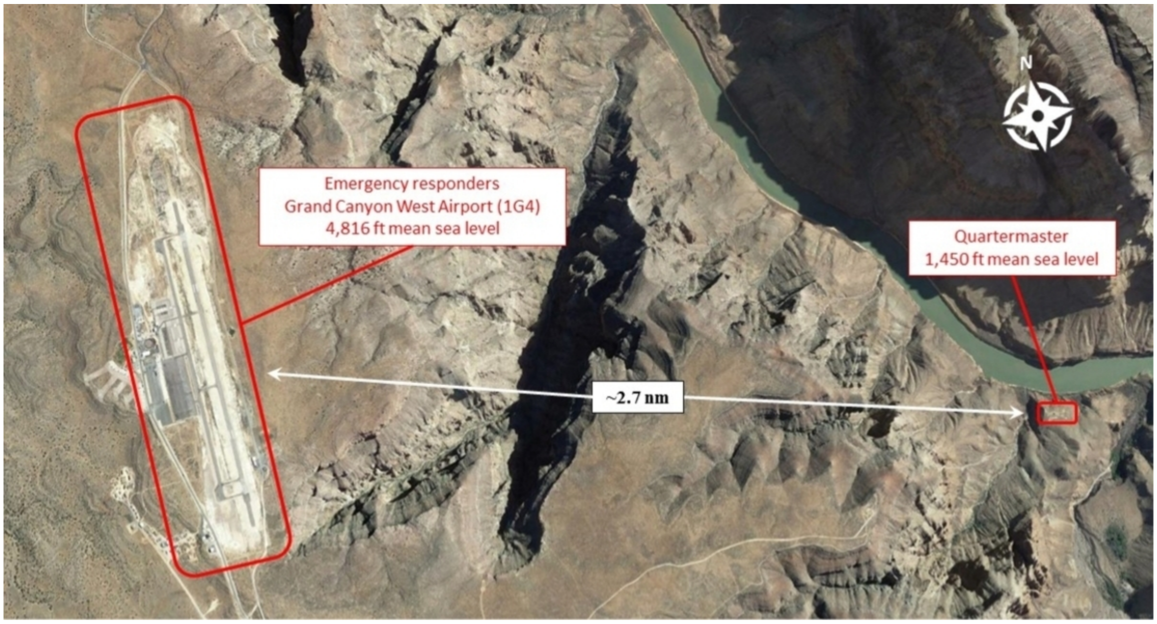

Figure 6. The location and terrain elevation difference between first responders at Grand Canyon West Airport and Quartermaster

The seriously injured occupants were eventually extracted from the accident site via helicopter between 2315 and 0105 arriving at University Medical Center in Las Vegas between 0055 and 0128.

Some Papillon pilots noted that the use of satellite phones stored at Quartermaster was hindered due to dead batteries, poor coverage, and a lack of training in their operation. Papillon provided a laminated instruction card about use of the phones in their cases and stated that the phones were regularly tested. Additionally, Papillon stated there were spare batteries in the cases and the batteries were regularly replaced. Billing records confirmed the Quartermaster satellite phone was used in April, May, July and December 2017, and on the night of the accident.

At the time of the accident, the operator did not have a program in place to ensure that the satellite phones were regularly maintained, and staff were trained on their use. After the accident, the operator purchased new satellite phones with improved coverage, easier operability, and spare batteries. Papillon pilots were trained in their use and asked to demonstrate their proficiency in using the satellite phones. Additionally, Papillon purchased trauma kits and a collapsible stretcher that are now located in unlocked metal containers, readily available for emergency crews. Finally, Papillon provided its pilots with first aid training and developed procedures to inspect the emergency medical equipment quarterly.

ADDITIONAL INFORMATION

Loss of Tail Rotor Effectiveness (LTE)

According to FAA Advisory Circular 90-95, *"LTE is a critical, low-speed aerodynamic flight characteristic which can result in an uncommanded rapid yaw rate, which does not subside of its own accord and, if not corrected, can result in a loss of aircraft control."*

Information on this subject has been published by many organizations including the FAA and helicopter manufacturers.

The FAA Helicopter Flying Handbook (FAA-H-8083-21B) contains an in-depth discussion on LTE. Chapter 7, Helicopter Performance, addresses helicopters with main rotors that rotate counter-clockwise, and states:

"The wind direction is also an important consideration. Headwinds are the most desirable as they contribute to the greatest increase in performance. Strong crosswinds and tailwind may require the use of more tail rotor thrust to maintain directional control. This increased tail rotor thrust absorbs power from the engine, which means there is less power available to the main rotor for the production of lift. Some helicopters even have a critical wind azimuth or maximum safe relative wind chart. Operating the helicopter beyond these limits could cause a loss of tail rotor effectiveness."

Chapter 11, Helicopter Emergencies and Hazards, defines LTE as a condition that occurs when the flow of air through a tail rotor is altered in some way, by altering the angle or speed at which the air passes through the rotating blades of the tail rotor disk. It further states…

The main factors contributing to LTE are:

1. *Airflow and downdraft generated by the main rotor blades interfering with the airflow entering the tail rotor assembly.*
2. *Main blade vortices developed at the main blade tips entering the tail rotor disk.*
3. *Turbulence and other natural phenomena affecting the airflow surrounding the tail rotor.*
4. *A high-power setting, hence large main rotor blade pitch angle, induces considerable main rotor downwash and hence more turbulence than when the helicopter is in a low power condition*
5. *A slow forward airspeed, typically at speeds where translational lift and translational thrust are in the process of change and airflow around the tail rotor will vary in direction and speed.*
6. *The airflow relative to the helicopter;*
    a. *Worst case – relative wind within ± 15° of the 10 o'clock position, generating vortices that can blow directly into the tail rotor. This is dictated by the characteristics of the helicopter's aerodynamics of tailboom position, tail rotor size and position relative to the main rotor and vertical stabilizer size and shape.*
    b. *Weathercock stability – tailwinds from 120° to 240°, such as left crosswinds, causing high pilot workload.*
    c. *Tail rotor vortex ring state (210° to 330°). Winds within this region will result in the development of the vortex ring state of the tail rotor.*
7. *Combinations of (a, b, c) of these factors in a particular situation can easily require more antitorque than the helicopter can generate and in a particular environment LTE can be the result.*

…There are a number of contributing factors, but what is more important in preventing LTE is to note them, and then to associate them with situations that should be avoided. Whenever possible, pilots should learn to avoid the following combinations:

1. *Low and slow out of ground effect.*
2. *Winds from ±15° of the 10 o'clock position and probably on around to 5 o'clock position*
3. *Tailwinds that may alter the onset of translational lift and translational thrust, and hence induce high power demands and demand more antitorque than the tail rotor can produce.*
4. *Low speed downwind turns.*
5. *Large changes of power at low airspeeds.*
6. *Low speed flight in the proximity of physical obstructions that may alter a smooth airflow to both the main rotor and tail rotor.*

According to Eurocopter service letter no. 1673-67-04, published on February 4, 2005, several instances of a loss of yaw axis control occurred when "the [pilot's] action applied to the [right] yaw pedal was not enough (amplitude/duration) to stop [left] rotation as quickly as the pilot wished." In this situation, as the aircraft continues to rotate, the pilot may suspect a tail rotor failure and either climb or descend, which, respectively, can increase the leftward rotation, or cause the aircraft to tilt while rotating and subsequently contact the ground. In the cases mentioned, "given their altitude and weight conditions the tail rotors were far from their maximum performance limits."

The Eurocopter service letter addresses helicopters with main rotors that rotate clockwise, though loss of yaw control can occur with any helicopter with a tail rotor. A loss of yaw axis control can also occur when the helicopter is in fact operated beyond its performance limits (due to loading or environmental conditions or extreme maneuvers), and in this case even the prompt application full right pedal might not be sufficient to counter a left rotation.

Eurocopter service letter no. 1673-67-04 was superseded by Safety Information Notice 3297-S-00, issued by the manufacturer on July 3, 2019, that discussed the detection and recommended response to unanticipated yaw, emphasizing a prompt reaction with large amplitude of opposite pedal input.

Engineering Simulations of Accident Flight

As there was no recorded data available from the accident flight, the helicopter manufacturer performed engineering simulations with parametric data from an exemplar flight to compute the control authority required to match a route similar to the accident flight in various wind conditions. The results of these simulations are included in the public docket for this accident.

Landing Site Research

Title 14 *CFR* 136.1, National Air Tour Safety Standards, Applicability and Definitions, defined "suitable landing area" as:

an area that provides the operator reasonable capability to land without damage to equipment or injury to persons. Suitable landing areas must be site-specific, designated by the operator, and accepted by the FAA. These site-specific areas would provide an emergency landing area for a single-engine helicopter *or a multi-engine helicopter that does not have the capability to reach a safe landing area after an engine power loss.*

A certificate of authorization (COA) dated March 28, 1997, from the FAA to Papillon showed that Quartermaster was recognized as a landing site for Papillon's air tour service with the provision that Papillon obtain permission from the land owner for any non-emergency landings. At the time of the accident, Papillon had an active agreement with the Hualapai Nation to land air tours at the site.

Demarcation Line

According to the United States Army Flight Manual "Fundamentals of Flight,"

The demarcation line is the point separating upflow air from downflow air. It forms at the mountain's highest point and extends diagonally upward. The velocity of the wind and steepness of the uplift slope determines the position of the demarcation line. Generally, the higher the wind speed and steeper the terrain, the steeper the demarcation line…As wind increases above 20 kts, the demarcation line moves forward to the crest's leading edge. It then matches the slope's steepness. The severity of updrafts, downdrafts, and turbulence also increase. Under these conditions, the best landing spot is close to the forward edge (windward side) of the terrain feature. (See figure 7.)

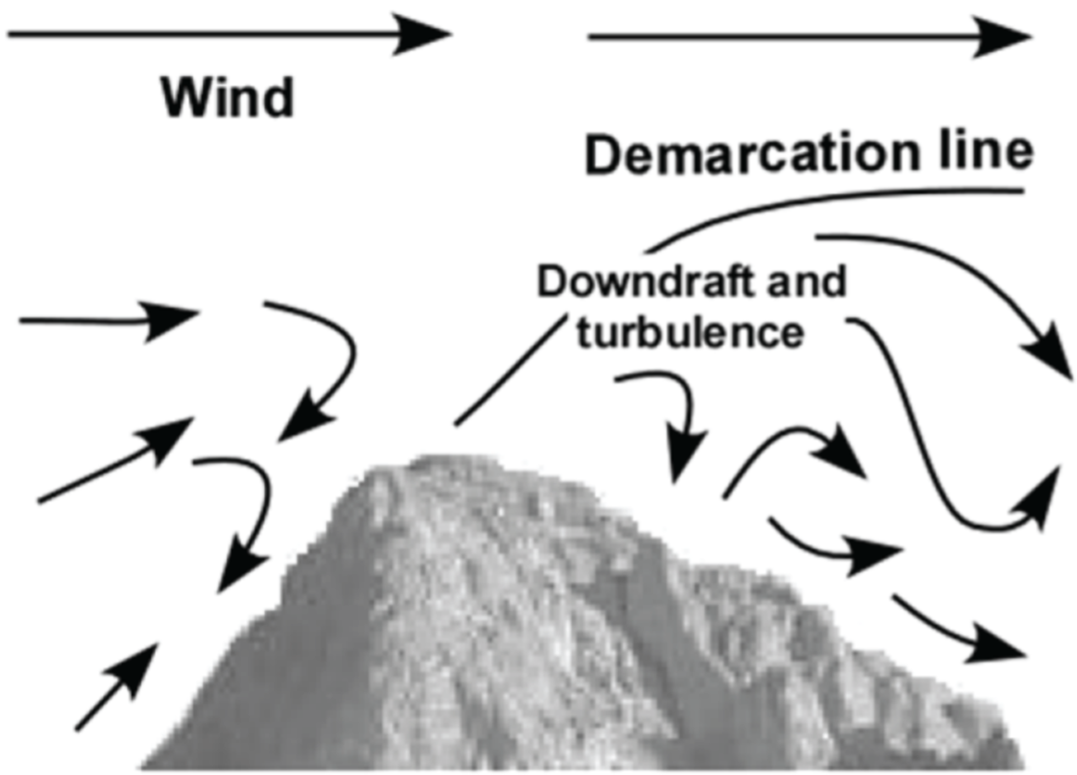

Figure 7: Excerpt showing demarcation line in strong wind from United States Army Helicopter Manual

A training document authored by The European Helicopter Safety Team entitled, "Techniques for Helicopter Operations in Hilly and Mountainous Terrain" stated:

…if the ground rises, the wind flows upward on a slope and it is referred to as the 'windward' side. If the ground slopes away from the wind direction, the wind flows downward and is referred to as the "leeward" side…When it flows over a cliff it tends to tumble over the edge in a turbulent manner.

The document further stated that,

On the leeward slope there is generally turbulence and downdrafts that can make flight hazardous and should be avoided. The area where the updraft turns to a downdraft is referred to the as "demarcation line." The demarcation line between updrafting and downdrafting air will, typically, become steeper and move towards the windward edge of the feature as wind speed increases.

Mechanical Turbulence

Papillon pilots remarked that the terrain features in the canyon adjacent to Quartermaster created mechanical turbulence, a weather phenomenon defined as the disturbance and transformation from horizontal wind to a complicated pattern of eddies and irregular air movements due to obstructions such as bluffs, hills, mountains or buildings.

Pinnacle and Ridgeline Operations

According to the FAA Helicopter Flying Handbook (FAA-H-8083-21B),

A pinnacle is an area from which the surface drops away steeply on all sides. A ridgeline is a long area from which the surface drops away steeply on one or two sides, such as a bluff or precipice. The absence of obstacles does not necessarily decrease the difficulty of pinnacle or ridgeline operations. Updrafts, downdrafts, and turbulence together with unsuitable terrain in which to make a forced landing may still present extreme hazards.

Papillon Terrain Flight Training and Guidance

When asked how they trained their pilots in mountainous flight operations, the company's Director of Operations stated that "all of our pilots come to us as commercially rated pilots proficient in these maneuvers and certified to competency by the FAA in rotorcraft." In addition, the operator required a minimum of 1,000 hours of pilot-in-command helicopter time before their employment. Each pilot was trained and evaluated in specific areas that aligned with concepts covered in the Helicopter Flying Handbook to prepare them for passenger flights in the Grand Canyon, including approaches, pinnacle/rooftop operations, confined area/steep approaches, crosswind operations, and loss of lift at altitude (settling with power).

The company used a "Flight Training Flow" as a guide for initial training in the EC130 B4 helicopter. According to this document, pinnacle and confined space operations are two of eight topics covered as part of a 1.3-hour instructional flight.

The "Pinnacle/Rooftop Operations" section of the company's training program stated that "the trainee shall accomplish a proper high and low reconnaissance."

Company guidance regarding approach and landing near pinnacles and ridgelines included excerpts from the FAA Helicopter Flying Handbook:

If there is a need to climb to a pinnacle or ridgeline, do it on the upwind side, when practicable, to take advantage of any updrafts. The approach flightpath should be parallel to the ridgeline and into the wind as much as possible.

Load, altitude, wind conditions, and terrain features determine the angle to use in the final part of the approach. As a general rule, the greater the winds are, the steeper the approach needs to be to avoid turbulent air and downdrafts…if a crosswind exists, remain clear of down-drafts on the leeward or downwind side of the ridgeline…When making an approach to a pinnacle, avoid leeward turbulence and keep the helicopter within reach of a forced landing area as long as possible.

Confined Area/Steep Approaches

According to the "Confined Area Operations" section of the company's training program, a high angle of descent should be used to complete a steep approach into the wind. Among the expectations listed under "Acceptable Performance Guidelines," the company expected the trainee to consider wind conditions, landing surface, obstacles, and to remain aware of the possibility of wind shear and/or wake turbulence.

Normal Approach to a Hover

The company's training program described a normal approach to a hover as its "accepted way to transition from cruising flight to a hover." The maneuver required a descent from 300 to 500 ft agl on a constant angle descent and constant airspeed until the helicopter is about 75 ft agl. The section continued by describing the maneuver in detail and incorporated the pilot's control movements.

Among the expectations listed under "Acceptable Performance Guidelines," the company expected the trainee to consider wind conditions, landing surface, obstacles, and to remain aware of the possibility of wind shear and/or wake turbulence.

Crosswind Operations

The company training on crosswind operations was meant to establish proficiency in approaches and landings when operations into the wind were not feasible. Most of the section discussed crosswind take-offs, as the section description makes only two references to a crosswind approach. The first reference stated that a "crosswind departure and approach in helicopter are similar to the operation in fixed wing." The second reference was captured in the "Acceptable Performance Guidelines" section, which stated "in addition to guidelines established for no wind approaches, all crosswind work will be evaluated on the basis of maintaining proper ground track."

The company operations manual imposed maximum wind limitations of 30-35 kts steady wind and a gust spread of 20 kts or greater; these limitations applied to both on- and off- airport operations.

Postaccident Safety Actions

Following the accident, Papillon took the following safety actions.

- ? Completed a crash resistant fuel system retrofit of its entire fleet of Airbus EC130 B4 and AS350B3e helicopters in August 2019
- ? Purchased survival equipment and trauma kits for each of its remote landing sites, including Quartermaster
- ? Installed an additional windsock near the accident site along with a weather station that transmits real-time wind information to Papillon's base of operations
- ? New satellite phones were placed at Quartermaster and other landing sites that include spare batteries. Pilots were trained on their usage.
- ? Upgraded their Spidetracks program, a GPS tracking platform, from a sampling rate of 15 minute intervals to 15 second intervals.
- ? Trained 12 employees as emergency response instructors to develop a module for employee training.
- ? Expanded the existing LTE training module in pilot training syllabus.
- ?

Following the accident, Airbus took the following safety action.

- ? The company's existing safety information notice on unanticipated left yaw (LTE) was revised on July 3, 2019.
- ? Safety information notice 3539-I-00 was released on September 4, 2020), which addresses the controllability differences between a conventional tail rotor and a Fenestron, which the accident helicopter was equipped with.

Pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	41,Male
Airplane Rating(s):	None	**Seat Occupied:**	Front
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	Helicopter; Instrument helicopter	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	November 13, 2017
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	December 21, 2017
Flight Time:	2423.1 hours (Total, all aircraft), 1078.6 hours (Total, this make and model), 2396.6 hours (Pilot In Command, all aircraft), 13.6 hours (Last 90 days, all aircraft), 2 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Eurocopter	**Registration:**	N155GC
Model/Series:	EC130 B4	**Aircraft Category:**	Helicopter
Year of Manufacture:	2010	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	7091
Landing Gear Type:	Skid	**Seats:**	8
Date/Type of Last Inspection:	January 25, 2018 100 hour	**Certified Max Gross Wt.:**	5350 lbs
Time Since Last Inspection:	168 Hrs	**Engines:**	1 Turbo shaft
Airframe Total Time:	9629.1 Hrs as of last inspection	**Engine Manufacturer:**	Turbomeca (Safran)
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	Arriel 2B1
Registered Owner:	XEBEC LLC	**Rated Power:**	847 Horsepower
Operator:	Papillon Airways, Inc.	**Operating Certificate(s) Held:**	Rotorcraft external load (133), On-demand air taxi (135), Commercial air tour (136), Agricultural aircraft (137)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	PRIV,4815 ft msl	**Distance from Accident Site:**	3 Nautical Miles
Observation Time:	17:45 Local	**Direction from Accident Site:**	337°
Lowest Cloud Condition:	Scattered / 12000 ft AGL	**Visibility**	
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	17 knots / 22 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	340°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.86 inches Hg	**Temperature/Dew Point:**	12°C / -6°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	BOULDER CITY, NV (BVU)	**Type of Flight Plan Filed:**	Company VFR
Destination:	Peach Springs, AZ (QMB)	**Type of Clearance:**	None
Departure Time:	16:42 Local	**Type of Airspace:**	Class G

Airport Information

Airport:	PRIV QMB	**Runway Surface Type:**	Dirt
Airport Elevation:	1451 ft msl	**Runway Surface Condition:**	Dry
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	Full stop

Wreckage and Impact Information

Crew Injuries:	1 Serious	**Aircraft Damage:**	Destroyed
Passenger Injuries:	5 Fatal, 1 Serious	**Aircraft Fire:**	On-ground
Ground Injuries:		**Aircraft Explosion:**	Unknown
Total Injuries:	5 Fatal, 2 Serious	**Latitude, Longitude:**	35.967224,-113.76889(est)

Administrative Information

Investigator In Charge (IIC):	Stein, Stephen
Additional Participating Persons:	Patrick Hempen; Federal Aviation Administration; DC John Waugh; Federal Aviation Administration; Las Vegas, NV Yann Torres; Bureau d'Enquêtes et d'Analyses ; Toulouse John Becker; Papillon Airways, Inc.; Boulder City, NV Seth Buttner; Airbus Helicopters; Grand Prairie, TX Bryan Larimore; Safran Helicopter Engines; Grand Prairie, TX Michael Heeman; Federal Aviation Administration; Forth Worth, TX
Original Publish Date:	January 14, 2021
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=96722