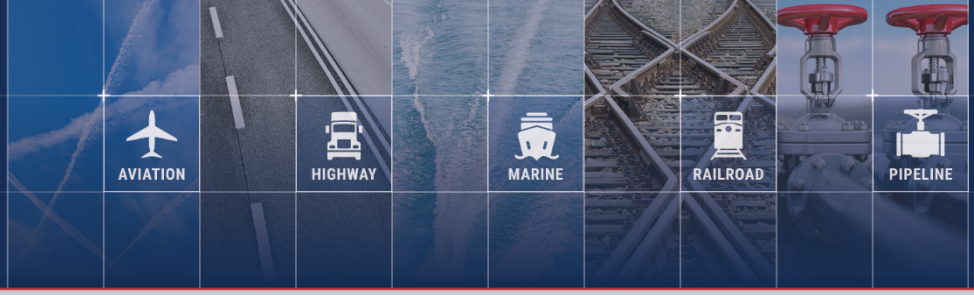

Aviation Investigation Final Report

Location:	Hawthorne, California	**Accident Number:**	WPR16FA086
Date & Time:	March 21, 2016, 12:01 Local	**Registration:**	N670EM
Aircraft:	Airborne XT 912	**Aircraft Damage:**	Destroyed
Defining Event:	Aircraft wake turb encounter	**Injuries:**	1 Fatal
Flight Conducted Under:	Part 91: General aviation - Instructional		

Analysis

The student pilot of the weight shift control (WSC) light sport aircraft, commonly referred to as a "trike," advised the air traffic control (ATC) tower that she was ready for departure and was instructed to hold short. A DeHavilland DHC-6 then landed, and, about 40 seconds later, the controller cleared the trike for departure on the same runway. When the trike was about 50 ft above ground level, it entered a steep right bank and descended to ground impact just north of the east-west runway. Postaccident examination of the airframe and engine did not reveal evidence of any pre-impact anomalies. Trajectory comparisons of the two aircraft, revealed that the trike likely encountered one of the wingtip vortices from the DHC-6, and the strength of that vortex, depending on the encounter geometry, likely far exceeded the roll authority of the trike. This resulted in an airborne loss of control at an altitude too low for recovery.

Because the trike and the DHC-6 were of the same ATC weight category, no controller wake vortex advisory was required or issued, and all wake-separation decisions were the responsibility of the pilot. Despite the significant size and weight differences between the 10,500-pound DHC-6 and the 992-pound trike, the pilot opted to depart less than a minute after the DHC-6 landed. Review of the pilot's training syllabus indicated that wake vortices were part of the curriculum, but her actual knowledge and understanding of that subject could not be determined. Her training workbook appeared to be pristine and unused, and the instructor's signoffs appeared to all have been done in a single sitting, possibly even after the accident. This suggested the possibility that her training, academic knowledge, and study diligence left her inadequately prepared to appreciate and avoid the wake vortex hazard.

Although the toxicology results indicated that the pilot had smoked cocaine, it was not possible to determine whether or not the pilot was experiencing any effects from smoking cocaine or from withdrawing from cocaine at the time of the accident. Based on the levels of diphenhydramine found, the pilot may have been impaired by its effects (somnolence, slowed psychomotor responses) at the time of the accident.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: The weight shift control aircraft encounter with a wake vortex from a preceding airplane, which resulted in a roll upset at an altitude too low for recovery. Contributing to the accident was the accident pilot's failure to recognize the potential for a wake vortex encounter.

Findings

Personnel issues	Aircraft control - Pilot
Aircraft	Lateral/bank control - Attain/maintain not possible
Personnel issues	Identification/recognition - Pilot
Personnel issues	Decision making/judgment - Pilot

Factual Information

History of Flight

Takeoff	Aircraft wake turb encounter (Defining event)
Takeoff	Loss of control in flight

On March 21, 2016, about 1201 Pacific daylight time, an Airborne XT912 weight shift control (WSC) special light sport aircraft, N670EM, was destroyed when it impacted a fence and a roadway shortly after takeoff from Northrop/Hawthorne Municipal Airport (HHR), Hawthorne, California. The student pilot received fatal injuries. The aircraft was owned and operated by Pacific Blue Air (PBA) of Venice, California, and was based at HHR. The instructional flight was operated under the provisions of 14 *Code of Federal Regulations* Part 91. Visual meteorological conditions prevailed, and no flight plan was filed for the flight.

According to multiple witnesses, the aircraft initiated its takeoff roll from HHR's runway 25 at a point before the displaced threshold. Just after liftoff, the aircraft began to bank and turn right and continued to do so until its flight track was nearly perpendicular to the runway heading. The initial segment of the flight was a climb but became a descent as the aircraft rolled and turned right. Witness estimates of the aircraft's maximum altitude ranged between 40 and 200 ft, and their maximum bank angle estimates ranged between 45° and 90°. All witnesses reported that the engine rpm either remained constant or increased during the flight and that the engine continued to run at least until impact. None of the witnesses mentioned the presence of any other aircraft.

The aircraft struck the airport perimeter fence and then impacted a 4-lane road north of the airport that ran roughly parallel to runway 25. According to witnesses, on impact, the aircraft immediately caught fire. A water pumping/construction crew was working about 100 ft from where the aircraft impacted, and several of these workers responded to the site within a few seconds and attempted to rescue the pilot and extinguish the fire. Two Los Angeles County Sheriff's Department deputies, who were located several hundred feet from the impact site, responded within a minute of the accident. Air traffic control tower (ATCT) personnel notified HHR operations personnel of the accident, and they responded within a few minutes of the accident. Los Angeles County Fire Department (LACoFD) equipment and personnel also responded very shortly after the accident. The pilot was extracted from the wreckage and transported to a hospital. The wreckage was examined and documented on scene by Federal Aviation Administration (FAA) and National Transportation Safety Board (NTSB) personnel later the same day and was then recovered and transported to a secure facility for additional examination.

Student pilot Information

Certificate:	Student	**Age:**	41,Female
Airplane Rating(s):	None	**Seat Occupied:**	Front
Other Aircraft Rating(s):	None	**Restraint Used:**	Unknown
Instrument Rating(s):	None	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Sport pilot	**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	
Flight Time:	59 hours (Total, all aircraft), 21 hours (Total, this make and model), 0 hours (Last 24 hours, all aircraft)		

Pilot's Flight Experience

The pilot held an FAA student pilot certificate that was issued in May 2014. Review of her pilot's logbook indicated that her first flight was conducted in October 2013 and that she flew about 2 to 3 times per month thereafter. All flight time recorded in the logbook was in WSC aircraft, and the PBA Chief Pilot reported that the pilot had no flight time in any other type of aircraft.

All of the pilot's flight time through June 2015 was in an Evolution Revo WSC aircraft that was also owned by PBA. The logbook indicated that the pilot had accrued about 38 hours in the Revo before she switched to the accident aircraft. The pilot's first flight in the accident aircraft was on June 8, 2015, and all her subsequent flights were in the accident aircraft. The logbook indicated that the pilot had accrued about 21 hours in the accident aircraft. The pilot's first solo flight was accomplished on November 2, 2015, when she had a total flight experience of about 48 hours. The logbook listed 8 solo flights, with a total flight time of 6.9 hours. Her most recent flight, which was a solo cross-country flight, took place on March 16, 2016.

Except for two flights, all the pilot's dual flights were conducted with the PBA Chief Pilot.

Pilot's Recent Activities

According to the pilot's family, the pilot had experienced a significant snowboarding accident about 3 days before the accident flight. The family members reported that she struck her head or neck in that event. She was wearing a helmet, did not lose consciousness, but did suffer a "strained neck." The pilot's fiancé reported that she was sore from that event, but her behavior, personality, and mental acuity were unchanged. The pilot's fiancé reported that she was happy when she left their residence for the accident flight and that he did not speak to her after she left.

A PBA co-owner reported that she witnessed the pilot arrive at the airport and stay in her car on the phone for about 20 minutes. According to the co-owner, when the pilot came into the hangar she appeared "slightly agitated." Review of the pilot's telephone records indicated that between 1040 and 1122 she made five calls to four different numbers and received one call from one of those numbers. The longest call was 3 minutes in duration; the rest were 1 minute in duration. In that same period, she

was sent one text message from a fifth telephone number. The investigation did not determine the persons or agencies associated with those telephone numbers.

Aircraft and Owner/Operator Information

Aircraft Make:	Airborne	**Registration:**	N670EM
Model/Series:	XT 912 NO SERIES	**Aircraft Category:**	Weight-shift
Year of Manufacture:	2007	**Amateur Built:**	
Airworthiness Certificate:	Special light-sport (Special)	**Serial Number:**	XT-912-0214
Landing Gear Type:	Tricycle	**Seats:**	2
Date/Type of Last Inspection:	November 10, 2015 100 hour	**Certified Max Gross Wt.:**	992 lbs
Time Since Last Inspection:		**Engines:**	1 Reciprocating
Airframe Total Time:	400 Hrs as of last inspection	**Engine Manufacturer:**	Rotax
ELT:	Not installed	**Engine Model/Series:**	912
Registered Owner:	Pacific Blue Air	**Rated Power:**	80 Horsepower
Operator:	Pacific Blue Air	**Operating Certificate(s) Held:**	None

FAA information indicated that the aircraft, commonly referred to as a "trike," was classified and registered as a light sport aircraft (LSA). It was manufactured in 2007 and was equipped with a Rotax 912 series engine. The maximum takeoff weight was 992 lbs. The aircraft manufacturer (Airborne) was based in Australia, and the engine manufacturer (Rotax) was based in Austria. According to the PBA Chief Pilot, the aircraft was acquired by PBA about a year before the accident and was equipped with an "SST" model wing.

According to the aircraft manufacturer's publications, the SST wing is "a high performance flex wing, which utilises struts to react the negative flight and landing loads imposed on the wing airframe. Removal of the king post and associated top rigging results in a significant decrease in drag, which improves cruise performance and reduces fuel consumption." The documentation also stated that, "Handling is improved and speed ranges are increased... pitch stability is achieved by using wire braced washout struts…which serve to keep the trailing edge of the sail raised, maintaining washout and therefore pitch stability." The documentation closed by stating that, "The SST retains all of the great handling characteristics of the Airborne wing range. The performance benefit of the strutted version ...makes the XT912 / SST aircraft the choice for the discerning cross country pilot."

Review of the aircraft maintenance records revealed that the most recent annual condition inspection was completed on June 3, 2015, when the airframe and engine each had accumulated 232 hours since new. The most recent 100-hour inspection was completed on November 10, 2015. The records indicated that, at that time, the airframe and engine each had accumulated 400 hours since new. The maintenance records did not contain any entries documenting maintenance actions that were indicative of, or could be associated with, any previous significant damage or problems.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	HHR,65 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	11:53 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/ N/A
Altimeter Setting:	30.12 inches Hg	**Temperature/Dew Point:**	19°C / 11°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Hawthorne, CA (HHR)	**Type of Flight Plan Filed:**	None
Destination:	Hawthorne, CA (HHR)	**Type of Clearance:**	None
Departure Time:		**Type of Airspace:**	Class D

The 1153 HHR automated weather observation included calm winds, visibility 10 miles, clear skies, temperature 19°C, dew point 11°C, and an altimeter setting of 30.12 inches of mercury. The next HHR observation was issued at 1253 and reported winds from 270° at 8 knots.

About 8.5 minutes before the aircraft was cleared for takeoff, the ATCT local controller broadcast, "Attention all aircraft ATIS [automated terminal information service] lima is now current wind two six zero at four altimeter three zero one four." Between that broadcast and the accident, the local controller did not issue any other wind information to any of the aircraft that he was handling.

Airport Information

Airport:	Northrop/Hawthorne Municipal HHR	**Runway Surface Type:**	Asphalt
Airport Elevation:	65 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	25	**IFR Approach:**	None
Runway Length/Width:	4956 ft / 100 ft	**VFR Approach/Landing:**	None

FAA-published information indicated that HHR was equipped with a single paved runway, designated 7/25, which measured 4,956 ft by 100 ft. Runway 25 had a displaced threshold of 463 ft. Airport elevation was 65 ft above mean sea level.

HHR was situated in a mixed industrial/semi-urban area of the Los Angeles basin, within 3 miles of Los Angeles International Airport. Due to this location, HHR operations included a significant number and mixture of aircraft types, including many business aircraft. The accident operator (PBA) was a relatively long-term resident of HHR, and one of the very few, and possibly only, WSC aircraft operators at HHR. However, due to the nature of PBA's business, its operational frequency for WSC aircraft was high, frequently conducting several flights per day.

The airport was not equipped with a dedicated, on-site rescue and firefighting (RFF) division. As specified in the HHR Emergency Plan, the airport relied upon the services of the LACoFD. The nearest LACoFD station was located less than 1 mile from HHR, and personnel and equipment from that LACoFD station responded to the accident.

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:		**Aircraft Fire:**	On-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal	**Latitude, Longitude:**	33.92361,-118.33139(est)

The wreckage was located about 280 ft north of the HHR runway 7/25 centerline, and about 1,400 ft west of the east end of the paved runway surface. The airport boundary was a 6-ft-high steel chain link fence, and ground scars indicated that the aircraft struck and damaged the fence, and then first impacted the road about 15 ft north of the fence. The aircraft came to rest at the north edge of the road, adjacent to and in contact with a fenced electrical equipment enclosure. The fence damage, road scar, and wreckage formed a line that was perpendicular to the runway.

Except for the right main wheel assembly and about a dozen windscreen, fairing, and propeller fragments, all the wreckage was tightly contained. The airframe (carriage) and wing structure consisted primarily of aluminum tubing of varying diameters, stabilized by a number of steel cables. Portions of several tubes had been damaged or consumed by fire. The carriage came to rest on its right side, oriented with the nose pointed about southeast. All the steel cables remained intact and securely attached to the structure at each of their respective ends. The forward carriage frame and nose landing gear assembly was fracture- and/or fire-separated from the aft carriage frame. The right wheel assembly was fracture-separated from the aircraft just above where its three support struts attached to the wheel assembly. The wheel exhibited significant localized crush damage, consistent with contact with the top crossbar of the airport boundary fence.

The seats were not located/identified in the wreckage, consistent with consumption by fire. Four instruments (an airspeed indicator, a radio, a transponder, and an EFIS [electronic flight instrumentation system]) were identified in the wreckage, but all were severely fire-damaged. The airframe recovery parachute was found out of its container; it remained reefed/folded but was partially extended lengthwise, and much of it was fused or consumed by fire. The parachute extraction rocket was also found out of its container, and its propellant load was absent, consistent with having been consumed in the ground fire.

Detailed examination of the airframe wreckage did not reveal evidence of any pre-impact mechanical deficiencies or failures that would have precluded normal flight.

The engine remained attached to its steel frame portion of the carriage and did not exhibit any evidence of any preimpact failures. The engine sustained significant impact and fire damage, to the point where its pre-accident integrity and operability could not be ascertained.

The three-blade Warp Drive composite propeller remained attached to the engine. Two propeller blades were fracture-separated from the hub; the full lengths of all three propeller blades were identified on scene. All propeller damage was consistent with impact effects with the engine operating.

For additional details, refer to the NTSB public docket for this accident.

Communications

The HHR ATCT was operating at the time of the accident. The ATCT was a non-federal facility that was operated and staffed by the private contractor Serco. At the time of the accident, there were three controllers on duty in the ATCT. Those three individuals were performing the functions of ground control (GC), local control (LC), and controller-in-charge (CIC). All three controllers' statements indicated that each witnessed the airplane's right turn, descent, and impact. None of the three statements mentioned the presence or activity of any other aircraft.

Serco-generated transcripts of the ATCT communications with the accident aircraft were provided to the investigation. Review of these transcripts indicated that they did not document any communications with, or any references to, any other aircraft.

The investigation obtained and reviewed the archived radar tracking data for HHR for the period leading up to the accident. That data indicated that a DeHavilland DHC-6 conducted an approach to HHR runway 25 just before the accident. The radar coverage did not extend to ground level, but the DHC-6 did not re-appear, which was consistent with the DHC-6 landing at HHR.

The audio recordings of the HHR communications were obtained and reviewed, and these indicated that the DHC-6 landed about 40 seconds before the accident aircraft was cleared to depart from the same runway. The audio recordings indicated that the accident pilot radioed the LC that she was ready for departure and that the LC then held the accident aircraft until the DHC-6 landed. Once the DHC-6 vacated the runway, the LC cleared the accident pilot for takeoff. The LC did not issue any wake turbulence advisory to the accident pilot.

The two pilots of the DHC-6 reported that they both witnessed the accident and then discussed (between themselves) the possibility that the accident aircraft had flown into their wake, resulting in the pilot's loss of control and the accident.

Medical and Pathological Information

According to the FAA, the 41-year-old pilot had never had an aviation medical examination.
The Los Angeles County Medical Examiner, Los Angeles, California, performed an autopsy of the pilot and determined that the pilot's cause of death was "multiple traumatic injuries." No significant natural disease was identified. The toxicology screenings performed by the medical examiner found 0.22 ug/dl of diphenhydramine in chest blood and 0.05 ug/mL of benzoylecgonine in vitreous fluid. Diphenhydramine is a sedating antihistamine available over the counter in many products intended to treat colds, allergies, and induce sleep and is frequently sold with the name Benadryl. The therapeutic range for diphenhydramine in blood is 0.0250 to 0.1120 ug/ml. Diphenhydramine undergoes post mortem redistribution, and central levels may be elevated above peripheral levels by a factor of about three. Benzoylecgonine is a metabolite of cocaine.

Toxicology testing performed by the FAA's Bioaeronautical Sciences Research Laboratory, Oklahoma City, Oklahoma, identified cocaine (at a level too low to quantify), its metabolite benzoylecgonine at 0.029 ug/ml, and another metabolite that occurs with smoking cocaine, anhydroecgonine methyl ester (at a level too low to quantify) in cavity blood. In addition, diphenhydramine was identified at 0.326 ug/ml in cavity blood and at a level too low to quantify in liver tissue.

The active effects of cocaine include a rush of euphoria, heightened awareness, excitement, and irritability, and it can cause paranoia and hallucinations. As the level drops via metabolism, other effects including sleep disturbance, depression, irritability, and drug craving can occur.

Organizational and Management Information

PBA Information

PBA was based at HHR and was situated in a hangar on the southeast side of the airport. At the time of the accident, PBA owned and operated two aircraft, both of which were WSC aircraft. The hangar faced runway 25, served as the office for PBA personnel and customers, and housed at least one of PBA's two aircraft.

According to the chief pilot, he was a founding member and co-owner of PBA when it began operations about 3 years before the accident. Shortly after the company began, he sold his share to another individual, whom the chief pilot described as a "silent partner." The silent partner and the other co-owner had been the owners ever since. Neither of the co-owners held any FAA pilot certificates.

According to its website, PBA was "a Light Sport Aircraft training facility based in the scenic city of Los Angeles" that offered "introductory flight lessons as well as intermediate and advanced flight training" in their aircraft. The PBA website contained multiple references to the visual or experiential aspects of the flights, using phrases such as "breath taking views of scenic Southern California," "surreal moments," and "epic experience." The website's references to flight training included statements such as "Once in flight, you will have the opportunity to actually fly the aircraft " and "should you decide to continue your training." The "Yelp" website contained multiple reviews from persons who had made

flights in the PBA WSC aircraft; those reviews were all consistent with aerial tour activities.

PBA Aircraft Dispatch Sheets

In response to an NTSB request for the aircraft's sign-out records, the chief pilot responded that he did not use any such sheets or system. When asked how PBA tracked flight time for billing purposes, the co-owner stated that the aircraft was equipped with a timer that would be started manually by the chief pilot or the flying pilot. The lack of a sign-out system precluded the determination of the time on the airplane at the time of the accident or a record of the aircraft usage/flight history.

Altered Accident Pilot's Record

The pilot's flight bag had been left in the PBA hangar for the flight; this was not an unusual procedure, since there was no stowage capability on the aircraft. The day after the accident, NTSB investigators visited the PBA hangar and examined the contents of the pilot's flight bag. The pilot's flight logbook was in her flight bag.

A 3-ring binder that contained various pilot-related information and documents was maintained by PBA and provided to NTSB investigators for examination. One of the documents in that binder was the pilot's FAA student pilot certificate. That certificate had been photographed on the day of the accident (3/21/16) by Hawthorne Police Department personnel, and again by NTSB personnel on the following day (3/22/16). Comparisons of the photographs from the two different days revealed that the certificate had been altered in the period between when the two photographs were taken. The alteration was the addition of a hand-written solo cross-country flight endorsement dated 3/15/16 and signed by the PBA chief pilot. The chief pilot confirmed that he made the subject endorsement, but he did not provide any information as to why he altered the document after the accident.

Pilot's Training Information and Records

The Federal Aviation Regulations (FARs) specify the minimum requirements and standards for obtaining a pilot certificate with a WSC rating, and flight training organizations and instructors enable student pilots to meet these requirements via their curricula and training materials. According to information provided by the PBA chief pilot, the curriculum used for the pilot's training was contained in a "Training Syllabus & Work Book, Weight Shift Control Trike" (Paul Hamilton, 2014 edition).

The chief pilot provided the original hardcopy of the pilot's training syllabus workbook to NTSB investigators. The workbook contained the overall lesson plan and was subdivided into individual numbered modules. Each module contained a "Ground Lesson" and a "Flight Lesson" printed on separate pages. Each lesson page had multiple checklist-style topic lists that were to be initialed by either the instructor or the student pilot. Each lesson page also had two dedicated, separate signoff lines, one each for the student pilot and the instructor.

Review of the pilot's syllabus work book indicated that the "Flight Lesson" pages for the first twelve (of a total of fifteen) modules were fully initialed and signed as "completed" by the chief pilot. None of those pages was initialed or signed by the accident pilot. Only one of the "Ground Lesson" pages (that for Module 11) was initialed and signed by the chief pilot. As was the case for the "Flight Lesson"

pages, none of the "Ground Lesson" pages were initialed or signed by the accident pilot.

The syllabus workbook was observed to be in nearly pristine condition; all pages were consistently clean and new-appearing. None were stained or wrinkled, or exhibited any other indications of use. The syllabus workbook was spiral-bound, which precluded the easy removal or resequencing of pages. The pages were printed on both sides and numbered such that when the work book was opened, all the left-hand pages were even-numbered, and all the right-hand pages were odd-numbered. For all the modules, the "Flight Lesson" pages were on the even-numbered pages. For all the modules except one (Module 11), the "Ground Lesson" pages were on the odd-numbered pages. The Module 11 Ground Lesson was printed as an even-numbered page.

The investigation identified two patterns with the pages that were initialed and signed by the chief pilot. The first pattern was that all the lesson pages that were initialed and signed by the chief pilot were even-numbered pages, irrespective of whether they were Flight or Ground lessons. None of the odd-numbered lesson pages, which were all Ground lessons, were initialed or signed by either the chief pilot or the student pilot. The second pattern was that all of the Chief Pilot's initials, signatures, and date entries appeared to be written with the same ink and pen tip.

Student Pilot's Syllabus Wake Vortex Information

Within the twelve instructor-initialed modules of the accident pilot's syllabus workbook, "wake vortex" avoidance was cited in two flight lessons and two ground lessons. The first citation was in the ground lesson for Module 4, and the last citation was in the ground lesson for Module 11. The chief pilot reported that his training of the accident pilot used the workbook guidance and references. The investigation was unable to determine what other training or study, if any, the pilot had obtained or conducted regarding wake turbulence.

Additional Information

ATC Separation & Advisory Information

FAA guidance for air traffic controllers is published in the FAA Order JO 7110.65, "Air Traffic Control." According to the order, separation criteria are based upon the weight categories of the aircraft involved. The guidance listed four weight categories. In order of increasing weight, these were small, large, heavy, and super. Per the order, the small category is the lowest weight category and applies to aircraft weighing 41,000 pounds or less. The accident aircraft and the DHC-6, which weighed about 15 times what the accident aircraft weighed, were both in this category.

For two aircraft in the small category, the only ATC-required separation criterion was that the preceding landing aircraft (in this case, the DHC-6) had to be clear of the runway before the succeeding aircraft (in this case, the accident aircraft) could be cleared for takeoff from the same runway. There was no requirement to issue a cautionary wake turbulence advisory between two small category aircraft. Paragraph 2-1-20 (b) of JO 7110.65 stated, "Issue cautionary information to any aircraft if in your opinion, wake turbulence may have an adverse effect on it."

FAA Advisory Circular (AC) 90-23G, "Aircraft Wake Turbulence," discussed aircraft weight categories within the context of ATC separation minima. The AC reiterated the four weight categories described above. The only AC-designated separation criteria discussed in the AC were those for "minimum radar separation;" no explicit wake-separation criteria were presented.

The AC included the following two cautionary "Notes":
- Whether or not a warning or information has been given, the pilot is expected to adjust aircraft operations and flightpath as necessary to preclude wake encounters.

- When any doubt exists about maintaining safe separation distances between aircraft to avoid wake turbulence, pilots should ask ATC for updates on separation distance and groundspeed.

FAA Wake Vortex Behavior Information

Wake vortices are discussed in AC90-23G and Chapters 4 and 13 of the FAA Pilot's Handbook of Aeronautical Knowledge (PHAK, FAA-H8083-25).

According to the PHAK, wing lift generation "triggers the rollup of the airflow aft of the wing resulting in swirling air masses trailing downstream of the wingtips. After the rollup is completed, the wake consists of two counter rotating cylindrical vortices." The strength of the vortex is governed by the weight, speed, and shape of the wing of the generating aircraft. The vortex characteristics of any given aircraft can also be changed by the extension of flaps or other wing configuration devices, as well as by a change in speed. The greatest vortex strength occurs when the generating aircraft is heavy, clean, and slow.

The AC stated that the "vortices from an aircraft can pose a hazard to encountering aircraft. For instance, the wake of larger aircraft can impose rolling moments that exceed the roll control authority of smaller encountering aircraft." Wake vortices are rarely detectable visually. The PHAK advised pilots to avoid wake vortex encounters by two principal means: separation by flight path and separation by time. The AC stated that "pilots must learn to envision the location and movements of the vortices generated by other aircraft and to adjust their flightpath accordingly."

The guidance provided descriptions of vortex behavior, particularly regarding vertical and lateral travel. The PHAK stated that "trailing vortices have certain behavioral characteristics that can help a pilot visualize the wake location and take avoidance precautions. The vortex circulation is outward, upward, and around the wingtips… Tests have shown that vortices remain spaced a bit less than a wingspan apart, drifting with the wind, at altitudes greater than a wingspan from the ground. Tests have also shown that the vortices sink at a rate of several hundred feet per minute, and once about 100 to 200 feet above the ground, they tend to move laterally at about 2 to 3 knots, away from the generating airplane centerline. Vortices slow their descent and diminish in strength with time and distance behind the generating aircraft." The PHAK also stated that "most of the energy is within a few feet of the center of each vortex, but pilots should avoid a region within about 100 feet of the vortex core."

The guidance provided specific flight path strategies to avoid wake vortex encounters; the avoidance schemes were predicated on the subject airplane traversing a flight path that avoided the expected travel

paths of the vortices. Both documents discussed the effects of crosswinds on vortex behavior and cautioned that crosswinds of 1 to 5 knots could result in the upwind vortex remaining over the runway for a relatively long time.

Both sets of guidance also stated that pilots should wait "at least 2 minutes" for the vortices to dissipate, if they were unable to follow a flight path that would ensure minimal potential for a vortex encounter.

In their generic discussions, neither the AC nor the PHAK discussed vortex hazards or avoidance schemes in terms of explicit aircraft types, sizes, or weights; all size discussions were presented using the relative terms "larger" and "smaller."

The FAA WSC Aircraft Flying Handbook (FAA-H-8083-5) referred pilots to the PHAK and the Aeronautical Information Manual (AIM) for wake vortex information. The WSC Handbook also stated that "it is not recommended to take off immediately behind another aircraft, particularly large, heavily loaded transport airplanes because of the wake turbulence that is generated. Even smaller aircraft can generate vortices that can cause the WSC aircraft to lose control during takeoff. Always wait for aircraft vortices to clear before taking off."

Preceding Airplane

As noted previously, a DHC-6 landed on runway 25 about 40 seconds before the accident aircraft departed on the same runway. According to the pilots of the DHC-6, the airplane was a DHC-6-300 with a wingspan of 65 ft. It had a maximum landing weight of 12,300 pounds, but the pilots reported that their landing weight at HHR was about 10,500 pounds. The pilots reported that the approach and landing were flown with 20° of flaps, that they used the visual approach slope indicator (VASI) for their approach profile, and that their approach speed was 75 knots.

Vortex Modeling Results

The possibility that N670EM encountered the wake of the landing DHC-6 and that that encounter resulted in an airborne loss of control was investigated. The study was limited by the lack of definitive positional and temporal data for the two aircraft, and the lack of fine-resolution meteorological data. However, there was sufficient information to enable an assessment of the potential for such a wake encounter, as well as quantify the potential effects of the wake on N670EM.

The NASA Langley Aircraft Vortex Spacing System Predictor Algorithm (APA) was used to determine potential wake vortex location and strength values. The results indicated that the meteorological conditions, in combination with the relative times and flight paths of the two aircraft, allowed for the possibility of a wake encounter by N670EM. Specifically, the results indicate that the location of the DHC-6 left vortex between 60 and 80 seconds after that airplane overflew the threshold could have been in the proper location to be encountered by N670EM.

In addition, the residual vortex circulation strength would have been of sufficient magnitude to upset or even completely overpower N670EM by exceeding the available roll control. Depending on the location of the vortex core along N670EM's wing span, the vortex-induced rolling moments generally exceeded the N670EM roll capability provided by normal control inputs and could have been about four times the

N670EM roll capability for vortex core locations near the N670EM wing centerline.

For detailed information, refer to the Wake Vortex Study in the NTSB public docket for this accident.

Administrative Information

Investigator In Charge (IIC):	Huhn, Michael
Additional Participating Persons:	
Original Publish Date:	March 14, 2018
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=92866