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Freighter Strikes Trees During Nighttime 'Black-hole' Approach

Fatigue and a color-vision deficiency that affected the ability of the pilot flying to observe glide-path-indicator lights contributed to the flight crew's failure to conduct a stabilized approach.

FSF Editorial Staff

About 0537 local time on July 26, 2002, a Boeing 727-200F, which was being operated by Federal Express on a scheduled cargo flight, struck trees and terrain during a visual approach in nighttime visual meteorological conditions to Runway 09 at Tallahassee (Florida, U.S.) Regional Airport. The three flight crewmembers were seriously injured. The airplane was destroyed by the impact and subsequent fire.

The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable cause of the accident was "the captain's and first officer's failure to establish and maintain a proper glide path during the night visual approach to landing."

The report said, "Contributing to the accident was a combination of the captain's and first officer's fatigue, the captain's and first officer's failure to adhere to company flight procedures, the captain's and flight engineer's failure to monitor the approach, and the first officer's [the pilot flying's] color-vision deficiency."

The flight crew had begun duty in Memphis, Tennessee, about 0312 Tallahassee time [0212 local time in Memphis].

"The accident flight crew consisted of three reserve FedEx pilots," the report said. "The accident flight was the first time all three crewmembers had flown together; however, the captain and flight engineer had flown together once previously."

The captain, 55, told investigators that he had 13,000 flight hours to 14,000 flight hours. Company records showed that his B-727 experience included 861 flight hours as pilot-in-command, 515 flight hours as second-in-command and 1,378 flight hours as a flight engineer. He was hired by FedEx in April 1989.

"The captain's training records indicated that he had not seen FedEx's black hole[1] or CFIT [controlled flight into terrain] avoidance training modules, which were presented during recurrent training in 1995 and 1999, because he underwent upgrade — not recurrent — training in those years," the report said.

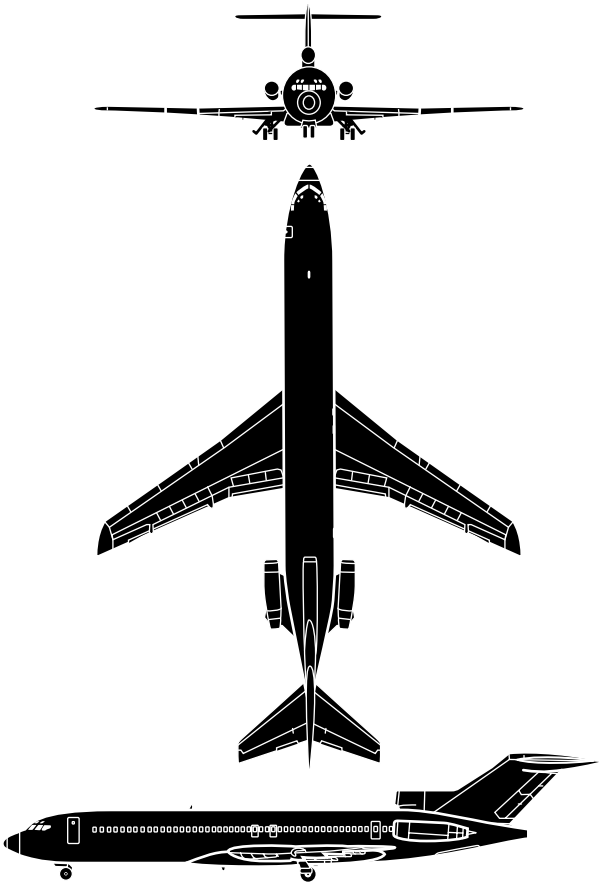
The captain's sleep during the two nights preceding the accident flight was interrupted several times when he arose to care for the family dog, whose health was deteriorating. On the night of the accident, he slept from about 2100 to about 0030.

"He described his sleep during that 3 1/2 hours as 'pretty good' and said that he did not feel fatigued when he subsequently arrived at [Memphis] for the accident flight," the report said.

The first officer, 44, told investigators that he had 7,500 flight hours to 8,500 flight hours. His B-727 experience included 526 flight hours as second-in-command and 1,457 flight hours as a

flight engineer. He was hired by FedEx in 1995 and received black hole and CFIT avoidance training in 1999.

The first officer served as a Lockheed P-3 pilot in the U.S. Navy for 16 years before being hired by FedEx. Navy records showed that the first officer passed all color-vision tests during his military career. In July 1995, he did not pass a color-vision test administered during a medical evaluation for a U.S. Federal Aviation Administration (FAA) first-class medical certificate. The test indicated that he had a mild red-green defect. Nevertheless, the FAA issued a first-class medical certificate to the first officer with a statement of demonstrated ability (SODA) based on his previous medical-examination results and his experience as a naval aviator.[2]



Boeing 727-200

Design of the three-engine, short/medium-range Boeing 727 began in 1959, and production of the B-727-100 began in 1963. The B-727-200 was introduced in 1967 with a fuselage lengthened by 20 feet (six meters) and seating for up to 163 passengers in standard configuration or 189 passengers in optional configuration (compared to 103 passenger seats in the 100 series). All B-727s have a three-pilot flight deck.

Pratt & Whitney JT8D-9 engines, each flat-rated at 14,500 pounds (6,577 kilograms) thrust, were standard. JT8D-11 engines, flat-rated at 15,000 pounds (6,804 kilograms) thrust and JT8D-15 engines, flat-rated at 15,500 pounds (7,031 kilograms) thrust, were options.

Maximum takeoff weight is 190,500 pounds (86,411 kilograms). Maximum landing weight is 160,000 pounds (72,576 kilograms). Maximum operating speed is 0.9 Mach.

Boeing produced a business-jet version and a freighter version of the B-727, and in 1971 introduced the Advanced B-727-200 with quieter JT8D-15 engines and more fuel capacity. B-727 production ceased in 1984.♦

Source: *Jane's All the World's Aircraft*

"When the first officer obtained his most recent first-class medical [certificate], dated Oct. 9, 2001, he was again issued the certificate with a SODA for the color-vision deficiency," the report said.

The first officer completed a flight at 0645 the day before the accident. After sleeping for five hours to six hours in a hotel and having dinner, he reported for duty again at 1818. His last flight that day was completed at 2303 in Memphis. He then was notified that he was scheduled to conduct the flight from Memphis to Tallahassee.

"The first officer stated that he accepted the … assignment after he ascertained that it did not violate existing FedEx/pilot union agreements and would not result in his exceeding flight [limits] and duty limits," the report said.[3] "He indicated that he slept for about 1 1/2 hours in a private sleep room in FedEx's crew rest facilities at [Memphis] before he met the captain to prepare for the accident flight. … He did note some fatigue but did not consider it to be unusual, given his schedule."

The flight engineer, 33, had about 2,600 flight hours, including 346 flight hours as a B-727 flight engineer. He was hired by FedEx in September 2001.

Forecast weather conditions for Tallahassee included a partially obscured sky, three statute miles (five kilometers) visibility in mist, with occasional scattered clouds at 500 feet and one statute mile (two kilometers) visibility in mist.

The flight was scheduled to depart from Memphis at 0412 but was delayed because of an adjustment to a cargo pallet. The airplane was pushed back from the gate about 0424. The report did not specify the actual departure time but said that the departure and cruise phases of flight were routine and uneventful.

At 0506, the captain said, "Right now, we are about two hundred miles out." The flight engineer established radio communication with a flight service specialist and requested information about weather conditions at the Tallahassee airport.

The specialist said, "Current Tallahassee, reporting one hundred scattered, one eight thousand scattered, two five thousand scattered, visibility niner, wind one two zero at five, temperature and dew point are two two." The specialist also provided an altimeter setting.

The flight engineer conveyed the information to the captain and first officer and said, "What runway [do] you think you're going to try for?"

The airport had two runways. The shorter runway, Runway 18-36, was closed for construction. Runway 09-27 was 8,000 feet (2,440 meters) long and had a precision approach path indicator (PAPI) at both ends. An instrument landing system (ILS) procedure was published for Runway 27. Airport surveillance radar (ASR) approach minimums were published for Runway 09.

The crew discussed the weather conditions and airport conditions. The flight engineer said that the airport's CFIT-risk rating was "moderate." The captain said that they would plan for a visual approach to Runway 27 and "back it up" with the ILS approach. He then briefed the first officer and flight engineer on the ILS approach procedure and the target approach speeds, including 137 knots for the landing reference speed (V_{REF}).

During this time, the crew began the descent from cruise altitude and communicated with FedEx airport-ramp personnel and Jacksonville (Florida) Center controllers. The airplane was northwest of the airport.

At 0519, the first officer asked the captain if he wanted to land on Runway 09. The captain said, "Yeah, maybe," and then said that landing on Runway 09 would result in a longer taxi to the ramp and that "[the] way we're coming in, probably two seven [will] be about as easy as any of them."

The flight engineer said that the airport's CFIT-risk rating was "moderate."

The crew then conducted the "In-range" checklist and activated the pilot-controlled airport lighting system.[4] At 0524, the captain said, "I don't know. [Do] you want to try for nine?"

The first officer said, "We're pointed in the right direction. I don't know. Like you said … kind of a long taxi-back. … I always thought you were supposed to land with the prevailing wind … at an uncontrolled [airport]."

The captain said, "Well, at five knots, it really, uh, you know. … The only advantage you have landing to the west … you have the [ILS] glideslope, which you don't have to the east." He then asked the first officer if he was familiar with the airport. The first officer said no, and the captain said that the lights of the downtown area were straight ahead and indicated where the airport beacon would come into sight.

The airport control tower was not in operation; it was scheduled to begin operating at 0600. The crew maintained radio communication with Jacksonville Center.

At 0528, the flight engineer said, "You want the 'Approach' checklist, seeing we're pretty much on our own?"

The first officer said, "We ever decide if we're going nine or two seven?"

The captain said, "Yeah, we can do nine if you want to."

The first officer said, "OK, runway nine, visual runway nine, PAPI on the left-hand side." He then called for the "Approach" checklist.

The controller had instructed the crew to descend to 3,000 feet and to report when they had the airport in sight.

At 0529, the captain said, "You want to call the field?"

The first officer said, "Yeah. I don't see the runway yet, but I got the beacon."

The captain told the controller that the airport was in sight and that they would land on Runway 09. The flight crew did not request an ASR approach. (If they had requested an ASR approach, the controller would have provided radar vectors to help the crew establish the airplane on the final approach course.) The controller cleared the crew to conduct a visual approach.

At 0530, the captain told the controller that the airplane was on an extended left base leg for Runway 09. Recorded air traffic control (ATC) radar data showed that the airplane was on a left base leg angled about 45 degrees to the extended runway centerline.

The first officer said, "OK, I think I got a runway now."

The captain and first officer then discussed the location of the airport beacon and runway lights, and began to extend the flaps in increments.

At 0532, the first officer said, "Well, I hope I'm looking in the right spot here."

The captain indicated the location of the airport beacon: "See that group of bright lights kind of to the south down there, and you see the beacon in the middle of it? You're kind of on about [a] ten-mile left base or so."

"OK," the first officer said. "So, I was looking at the wrong flashing light, then. … With the direction I took, we could have used two seven, eh?"

"Yeah, it [doesn't] matter," the captain said.

At 0534, the captain said, "I guess the lights came on. If not, I'll click them again here … when we get a little closer." About 20 seconds later, the cockpit voice recorder (CVR) recorded sounds similar to a microphone being keyed five times in about 1.5 seconds and the captain saying, "There we go."

The first officer called for "flaps 15, gear down" and the "Before Landing" checklist. As the flight engineer and first

officer conducted the checklist, the captain told the controller that the airplane was being turned onto final approach.

At 0536:25, the CVR recorded a sound similar to a high-speed elevator-trim wheel in motion, a ground-proximity warning system (GPWS) callout of 1,000 feet and the first officer saying, "Sorry about that. I was lined up on that paper mill or something."

The captain said, "That's all right. No problem."

The FedEx flight operations manual (FOM) stated that during a visual approach, an airplane should be established on final approach in a position and at an altitude sufficient to ensure that the approach is stabilized when the airplane is 500 feet above ground level (AGL). The FOM stated that at 500 feet AGL, the pilot not flying must determine whether the approach is stabilized or is not stabilized and to call either "stable" or "unstable, go around."

"The non-flying pilot is also [required] to advise the flying pilot of any deviations in airspeed (more than five knots off target airspeed below 1,000 feet), sink rate (no more than 1,000 feet per minute below 1,000 feet) and glideslope and localizer (if available) during the visual approach," the report said.

The FOM defined a stabilized approach as follows:

- "The aircraft must have landing gear down and locked; the flaps/slats must be in the final landing configuration;
- "The engines must be spooled up and steady at the proper approach setting [which was about 1.3 engine pressure ratio (EPR)[5] to 1.45 EPR during the accident airplane's approach to Tallahassee];
- "The proper descent angle and rate of descent must be established and maintained. All available landing aids (ILS, VASI [visual approach slope indicator], PAPI, etc.) must be used. Nonprecision approaches may require a slightly steeper angle until reaching the MDA (minimum descent altitude); [and,]
- "Airspeed must be stable and within the range of target speed (+/– five knots of target). Momentary and minor deviations are tolerated if immediate corrections are made."

The report said, "Research indicates that during a time period from about midnight to 0600, and especially between 0300 and 0500, there is a higher probability of flight crew errors and accidents because a pilot's alertness and performance are degraded by fatigue. [A] common effect observed in fatigue-related accidents is a tendency to continue an approach despite increased cues indicating a need to discontinue the approach."

About 0536:37, the airplane was being turned from a left-base leg to final approach 2.5 nautical miles (4.6 kilometers) from the airport. A performance study conducted by investigators indicated that about this time, the PAPI — which consisted of four light boxes located near the runway threshold and arranged perpendicular to the runway centerline — likely displayed one white light and three red lights, as viewed from the flight deck, indicating that the airplane was slightly low (Figure 1, page 5). Three seconds later, the PAPI likely displayed four red lights, indicating that the airplane was too low. (A PAPI display of two white lights and two red lights indicates that the aircraft is on a three-degree glide path to the runway.)

Engine power was increased briefly from about 1.05 EPR to 1.24 EPR and then was decreased to 1.17 EPR.

"About 0536:43, as the airplane approached 500 feet, the captain asked the first officer if he wanted to go to flaps 30, and the first officer responded 'please,'" the report said.

At 0536:48, the CVR recorded a GPWS callout of 500 feet and the captain saying "stable." The performance study indicated that the airplane was 1.8 nautical miles (3.3 kilometers) from the runway and descending at 1,248 feet per minute; airspeed was 152 knots.

"Although the airplane's airspeed was within the target range, the airplane did not meet FedEx's criteria for a stabilized approach because its rate of descent was greater than FedEx's recommended 1,000 feet per minute, the engines' power settings were less than the expected 1.3 [EPR] to 1.45 EPR, and its glide path was low, as indicated by the PAPI light guidance," the report said.

At 0536:49, the first officer said, "I'm going to have to stay just a little bit higher, or I'm going to lose the end of the runway." Flight data recorder (FDR) data indicated that engine power increased from 1.17 EPR to 1.20 EPR. The descent rate decreased from 1,400 feet per minute to about 960 feet per minute, but the airplane remained below the proper glide path.

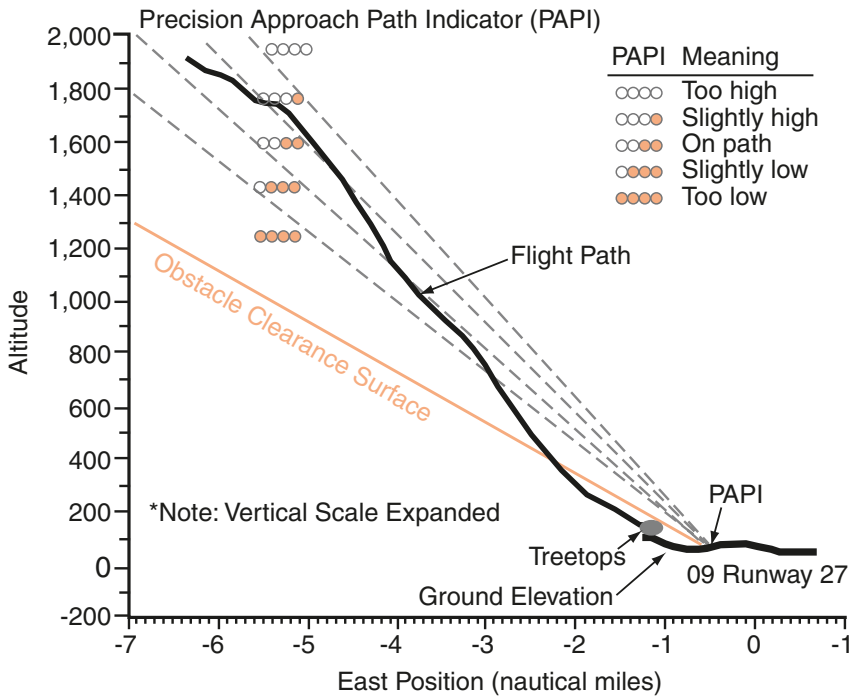
Investigators did not determine why the first officer reduced the descent rate.

"It is possible that he was trying to reconcile a conflict between the 500-foot GPWS callout and a mistaken illusion of the airplane's elevation above the field [possibly caused by the black-hole effect and by a slight upslope of the runway]," the report said.

The reduction of the descent rate likely was not done in response to recognition that the PAPI was showing four red lights.

"Recognition of four red PAPI lights at such a late stage in the approach should have resulted in a more aggressive response (such as an immediate climb or a go-around)," the report said.

Flight Path of FedEx Flight 1478; Boeing 727-200F; July 26, 2002



Source: Adapted from U.S. National Transportation Safety Board

Figure 1

In response to the first officer's statement that he was going to "lose the end of the runway," the captain said, "Yeah, OK. … It is starting to disappear in there a little bit, isn't it. Think we'll be all right. Yeah."

The performance study indicated that the airplane was 0.9 nautical mile (1.7 kilometers) from the runway, descending through about 200 feet AGL at 528 feet per minute; airspeed was 146 knots.

The report said that the first officer's statement ("I'm going to lose the end of the runway") and the captain's statement ("it is starting to disappear") indicate that the crew might have encountered a temporary obstruction to visibility, such as clouds or mist.

"Although a temporary obstruction might help explain the flight crew's failure to recognize the PAPI guidance while that obstruction was present, it does not explain why the three pilots failed to recognize the presence of four red PAPI lights throughout the rest of the approach," the report said. "Further, according to FedEx procedures (and FAA regulations), if the approach end of the runway became obscured at any time during the visual approach, the pilots should have performed a go-around."

The crew conducted the approach over a national forest area with no ground lights or other visible references that would provide clues to their height above terrain.

"FedEx's recurrent training module on black-hole approaches, which the first officer received in 1999, warned that pilots conducting visual approaches at night over terrain with minimal visible ground features or lighting often perceive the airplane to be higher than its actual altitude," the report said. "Research has shown that in situations like this, a pilot typically flies a lower-than-normal approach until the error starts to become apparent (usually about two [nautical miles] to three miles [four kilometers to six kilometers] from the runway), at which time the pilot takes corrective action.

"Indeed, on the night of the accident, the first officer did fly a concave approach, with a steeper-than-normal initial descent, which is characteristic of a black-hole approach. … PAPI lights … are a recognized countermeasure for use in black-hole conditions and should have been, but were not, effectively used to maintain an appropriate glide path."

At 0537:13, the flight engineer said that the "Before Landing" checklist was complete. This was the last crewmember statement recorded by the CVR.

At 0537:14, the CVR recorded a GPWS callout of 100 feet. FDR data indicated that engine power increased to 1.34 EPR, then to 1.46 EPR. The CVR recorded GPWS callouts of "50," "40," "30" and "bank angle, bank angle," dispersed among several sounds of "crunches" and a "loud squeal" before the recording ended at 0537:36.

The airplane struck trees about 3,650 feet (1,113 meters) from the approach end of the runway. The wreckage path extended about 2,094 feet (639 meters) through the wooded area. The crew exited the airplane through a sliding window on the left side of the flight deck before the fire spread to the flight deck.

The report said that, contrary to FedEx procedures, the flight crew did not work together effectively to fly and monitor a stabilized approach.

"There was no evidence to suggest that the deficient crew coordination was a characteristic pattern of performance for these three crewmembers (a review of company records and interviews with other pilots generated positive and complimentary descriptions about their abilities)," the report said.

Citing a study by the Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force that found inadequate monitoring to be a factor in 63 percent of approach-and-landing accidents, the report said, "The circumstances of this accident demonstrate the importance of flight crewmembers actively monitoring the performance of other crewmembers, as well as their own performance."

To emphasize the importance of monitoring, FedEx after the accident changed the term "pilot not flying" to "pilot monitoring." The FOM was revised to require both visual approaches and instrument approaches to be stabilized when the airplane is 1,000 feet AGL, and to specify the types of approaches and landing aids that pilots must use when the destination airport's control tower is not in operation.

"FedEx also revised its practices to require that only airplanes equipped with operating enhanced GPWS (EGPWS)[6] and traffic [alert and] collision avoidance systems (TCAS) be dispatched to non-tower and high-CFIT-risk airports," the report said. "Further, the company stated that it planned to have EGPWS and TCAS installed in all its airplanes by late 2004."

The first officer told investigators that he never had experienced difficulty distinguishing red and white PAPI lights and VASI lights. At NTSB's request, the first officer completed an extensive ophthalmic evaluation administered by the U.S. Air Force School of Aerospace Medicine (USAFSAM).

"During this evaluation, the first officer passed the FALANT [Farnsworth Lantern[7]] color-vision screen but failed seven additional red-green color-vision tests," the report said. "The USAFSAM specialists' report stated that the first officer had a severe congenital deuteranomaly that could result in 'difficulties interpreting red-green [signal lights] and white signal lights.'"

A deuteranomaly is "a common color-vision deficiency, present in about 5 percent of the male population, in which the pigments of the eye that typically respond to the middle range of color wavelengths have a sensitivity shifted to longer wavelengths," the report said.

The USAFSAM specialists said that the first officer "would definitely have had problems discriminating the PAPI [lights] as they were designed because the red lights would appear not to be red at all, but … some other wavelength that would make them more indistinguishable from white."

Most individuals with color-vision deficiencies develop an ability to differentiate between colors by differences in shade or brightness, the USAFSAM specialists said.

"The length of the first officer's military [aviation career] and civilian aviation career suggests that, in general, he had been able to compensate for his deficient color vision," the report said. "However, during the approach to Runway 09 at [Tallahassee], the first officer had to rely more heavily on his color vision because the PAPI lights were the only reliable source of glide path information in the black-hole approach environment. The first officer's interpretation of the PAPI lights would have been even more challenging because all four lights were red during most of the final approach."

The report said that in addition to passing the FALANT test during his postaccident evaluation by USAFSAM, the first officer passed a light-gun-signal test administered by an FAA aviation medical examiner.

USAFSAM specialists told investigators that other color-vision tests, including the pseudoisochromatic plate (PIP) test,[8] have failed to detect color-vision deficiencies in pilot applicants and that the U.S. Navy now uses a battery of tests to identify color-vision deficiencies in applicants.

Based on these findings, NTSB made the following recommendations to FAA:

- "Conduct research to determine the effectiveness of each of the current [FAA]-approved color-vision-test protocols (including the color-signal light test) at effectively screening out pilot applicants with color-vision deficiencies that could impair their ability to perform color-related critical aviation tasks including (but not limited to) correct interpretation of glideslope information and in-cockpit displays that use color to convey information. The research should take into account the time typically available to perform each task, particularly under emergency conditions, and the potential effects of mild hypoxia (as might occur at typical cabin altitudes on color-vision deficiencies. (A-04-46); [and,]

- "Based on the results of the research requested in Safety Recommendation A-04-46, develop a standard battery of tests to be performed at least once on each applicant for a [first-class medical certificate or second-class

medical certificate] that would prevent applicants with color-vision deficiencies that could impair their ability to perform color-related critical aviation tasks from being certificated without limitations. (A-04-47)."

[In response to the recommendations, FAA on Sept. 13, 2004, said that it would conduct research to identify, develop and validate a new color-vision test. FAA said that in conducting the research, it would do the following:

- "Conduct an extensive review of the literature related to color vision and performance on color-coded displays, with particular attention to the flight environment;

- "Establish a group of subject-matter experts from the aviation community to review existing and emerging aviation displays and the flight environment to identify systematically the use of color, to identify instances where color is used as a non-redundant cue and determine whether pilots who have a color-vision deficiency may respond in a manner that may compromise safety; (and,)

- "Use results of the review and analysis to develop a research study that assesses the ability of color-vision-deficient individuals to respond to information from cockpit displays and the aviation environment, as well as respond to simulated red-white VASI/PAPI lights under time-constricted conditions."

FAA said that the research would be completed in about 2.5 years and that the "results, along with those of research currently ongoing in other countries, will provide the necessary information regarding the modification of existing standards and the development of a revised testing protocol, including practical tests."]♦

[FSF editorial note: This article, except where specifically noted, is based on U.S. National Transportation Safety Board Aircraft Accident Report NTSB/AAR-04/02, *Collision With Trees on Final Approach; Federal Express Flight 1478; Boeing 727-232, N497FE; Tallahassee, Florida; July 26, 2002*. The 132-page report contains illustrations and appendixes.]

Notes

1. The black-hole effect typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).

2. U.S. Federal Aviation Regulations (FARs) Part 67, *Medical Standards and Certification*, states that issuance of a statement of demonstrated ability (SODA) may be based on "the person's operational experience and any medical facts that may affect the ability of the person to perform airman duties." Part 67.401, "Special issuance of medical certificates," states: "A SODA does not expire and authorizes a designated aviation medical examiner to issue a medical certificate of a specified class if the examiner finds that the condition described on its face has not adversely changed."

3. The report said that the agreement between FedEx and the FedEx pilots' union stated: "A pilot who is unable to operate his trip or a portion thereof due to fatigue shall notify [crew scheduling] immediately and shall be placed in sick-leave status. A fatigued pilot shall be compensated, and his sick leave account(s) shall be debited." The report said that none of the accident flight crewmembers had turned down a trip because of fatigue.

4. Pilot-controlled airport lights typically are activated by keying the microphone a specified number of times in a specified period on the common traffic advisory frequency or a discrete radio frequency.

5. Engine pressure ratio (EPR) — engine-exhaust pressure divided by engine-intake pressure — is used as an indication of engine-power output, with higher EPR values indicating higher engine-power output.

6. *Enhanced ground-proximity warning system* (EGPWS) and *ground collision avoidance system* are other terms used to describe terrain awareness and warning system (TAWS) equipment. TAWS is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration (FAA) to describe equipment meeting International Civil Aviation Organization standards and recommendations for GPWS equipment that provides predictive terrain-hazard warnings.

7. The report said that the Farnsworth Lantern (FALANT) test is accepted by FAA as a "color-vision-screening test for FAA pilot certification that is intended to identify (for exclusion) people with significant red-green color-vision deficiency who are unable to name aviation (and other) signal lights correctly, while 'passing' people with mild red-green vision deficiency. In this test, the applicant is asked to identify the color (red, green or white) of two lights projected by the FALANT machine. The examinee must identify nine different light pairings."

8. The report said that the pseudoisochromatic plate test involves the use of "cards with colored spots or patterns that are selected and arranged such that individuals with normal color vision will see a number or figure [in the pattern]."

Further Reading From FSF Publications

FSF Approach-and-landing Accident Reduction (ALAR) Task Force; FSF Editorial Staff. "ALAR Briefing Notes." *Flight Safety Digest* Volume 19 (August–November 2000).

FSF ALAR Task Force; FSF Editorial Staff. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 and Volume 18 (November–December 1998, January–February 1999).

Mohler, Stanley R. "Color Vision and Cockpit Operations." *Human Factors & Aviation Medicine* Volume 37 (May–June 1990).

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