Crash During Approach to Landing
Business Jet Services, Ltd.
Gulfstream G-1159A (G-III), N85VT
Houston, Texas
November 22, 2004

ACCIDENT BRIEF

NTSB/AAB-06/06
PB2007-100699

National Transportation Safety Board

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Aircraft Accident Brief

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Notation 7828
Adopted November 2, 2006

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2006. ***Crash During Approach to Landing Business Jet Services, Ltd., Gulfstream G-1159A (G-III), N85VT, Houston, Texas, November 22, 2004.*** **Aircraft Accident Brief NTSB/AAB-06/06. Washington, DC.**

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National Transportation Safety Board
Washington, D.C. 20594

Aircraft Accident Brief

Accident Number:	DCA05MA011
Aircraft and Registration:	Gulfstream III, N85VT
Location:	Houston, Texas
Date:	November 22, 2004
Adopted On:	November 2, 2006

HISTORY OF FLIGHT

On November 22, 2004, about 0615 central standard time,[1] a Gulfstream G-1159A (G-III), N85VT, operated by Business Jet Services Ltd., struck a light pole and crashed about 3 miles southwest of William P. Hobby Airport (HOU), Houston, Texas, while on an instrument landing system (ILS)[2] approach to runway 4. The two pilots and the flight attendant were killed, an individual in a vehicle near the airport received minor injuries, and the airplane was destroyed by impact forces. The airplane was being operated under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91 on an instrument flight rules flight plan. Instrument meteorological conditions (IMC) prevailed at the time of the accident.

The accident flight was scheduled to depart from Dallas Love Field Airport (DAL), Dallas, Texas, about 0500 as a positioning flight to HOU. The flight crew planned to pick up former President George H.W. Bush and other passengers at HOU and transport them to Guayaquil, Ecuador. The flight was scheduled to depart HOU about 0654.

The flight departed DAL about 0530. According to Business Jet Services' Flight Operations and Charter Sales Manager, the departure was delayed because of poor weather conditions at HOU and DAL. The captain was the flying pilot, and the first officer performed the nonflying pilot duties.

At 0543:32, the flight crew received HOU automatic terminal information service (ATIS) information "Quebec," which reported that the winds were calm, the visibility was

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[1] Unless otherwise indicated, all times in this report are central standard time based on a 24-hour clock.

[2] The ILS consists of a localizer and a glideslope, which provide lateral and vertical guidance, respectively, during an approach. Cockpit instrumentation shows the airplane's location relative to the glideslope and localizer signals. Displacement is shown in terms of the airplane's angular deviation above or below the glideslope and left or right of the localizer. Pilots can judge the amount of displacement by needle deflections that reference "dots" on the face of the instruments.

1/8 statute mile (sm) in fog, the runway visual range (RVR)[3] for runway 4 was variable between 1,600 and 2,400 feet, and the clouds were broken at 100 feet and overcast at 9,000 feet.[4] At 0547:50, the cockpit voice recorder (CVR) recorded the first officer starting the approach briefing. About 3 minutes later, the CVR recorded a discussion between the pilots about entering the navigational approach fixes CARCO, ELREN, EISEN, and Hobby (HUB) very high frequency omnidirectional range (VOR) in the airplane's flight management system (FMS). The captain asked, "we can probably delete HUB though, can't we?" The first officer replied, "yeah, we could 'cause we're gonna have that on here for our missed [approach point]." (See figure 1 for the runway 4 ILS published approach chart.)

At 0558:50, the first officer contacted the Houston Terminal Radar Approach Control (TRACON) and reported, "approach…Gulfstream eight five Victor Tango's with you out of one eight zero for one one thousand [feet], [ATIS] information 'Kilo.'"[5] The controller cleared the flight directly to CARCO, adding, "when you're able for the ILS runway four." The first officer acknowledged the transmission; however, he read back, "ILS runway one four" instead of " runway four." He then stated, "I'll set up our ILS, in here, one oh nine nine."

At 0605:05, the Houston TRACON controller instructed the flight crew to descend to and maintain 3,000 feet. Radar data indicated that, about this time, the airplane was at an altitude of about 11,000 feet and was located about 29 miles northwest of HOU. At 0609:33, the first officer started the before landing checklist, and, about 1 minute later, he stated, "five miles…from CARCO." At 0610:43, the controller instructed the flight crew to turn left heading 070° and to maintain an altitude of "2,000 feet or above 'til established [on the] localizer." The controller then cleared the flight for the ILS runway 4 approach. At 0611:13, the first officer stated, "localizer's alive." (See figure 2 for the accident airplane's ground track.)

[3] The RVR is the measurement of the visibility near the runway's surface. The measurement represents the horizontal distance that a pilot should be able to see down a runway from the approach end.

[4] Altitudes referenced in this report from surface weather observations and terminal aerodrome forecasts are reported as height above ground level. All other altitudes referenced in this report are reported as height above mean sea level.

[5] As noted previously, the first officer had actually received ATIS information "Quebec."

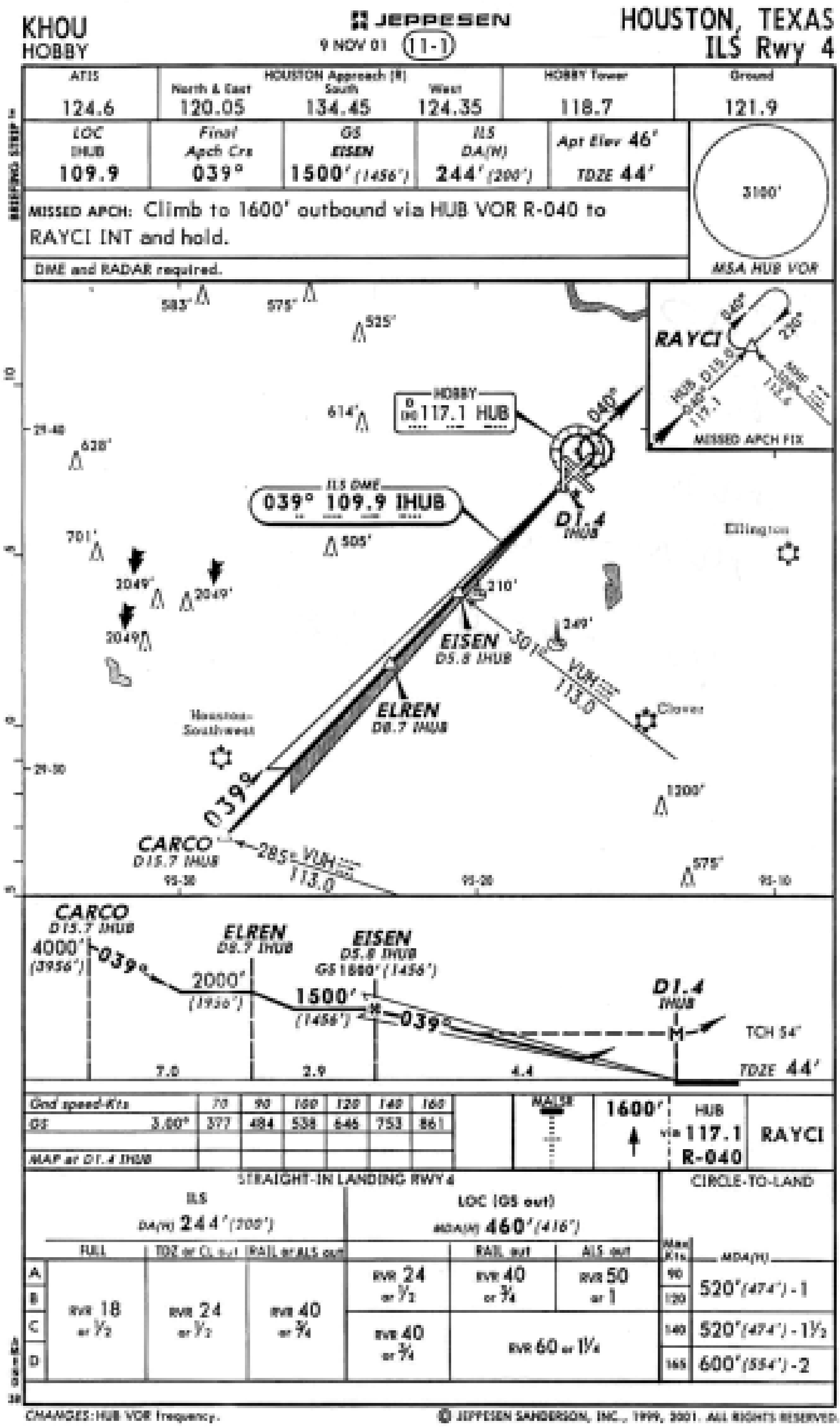

Figure 1. ILS runway 4 published approach chart. (Reproduced with permission of Jeppesen Sanderson, Inc. Not to be used for navigation.)

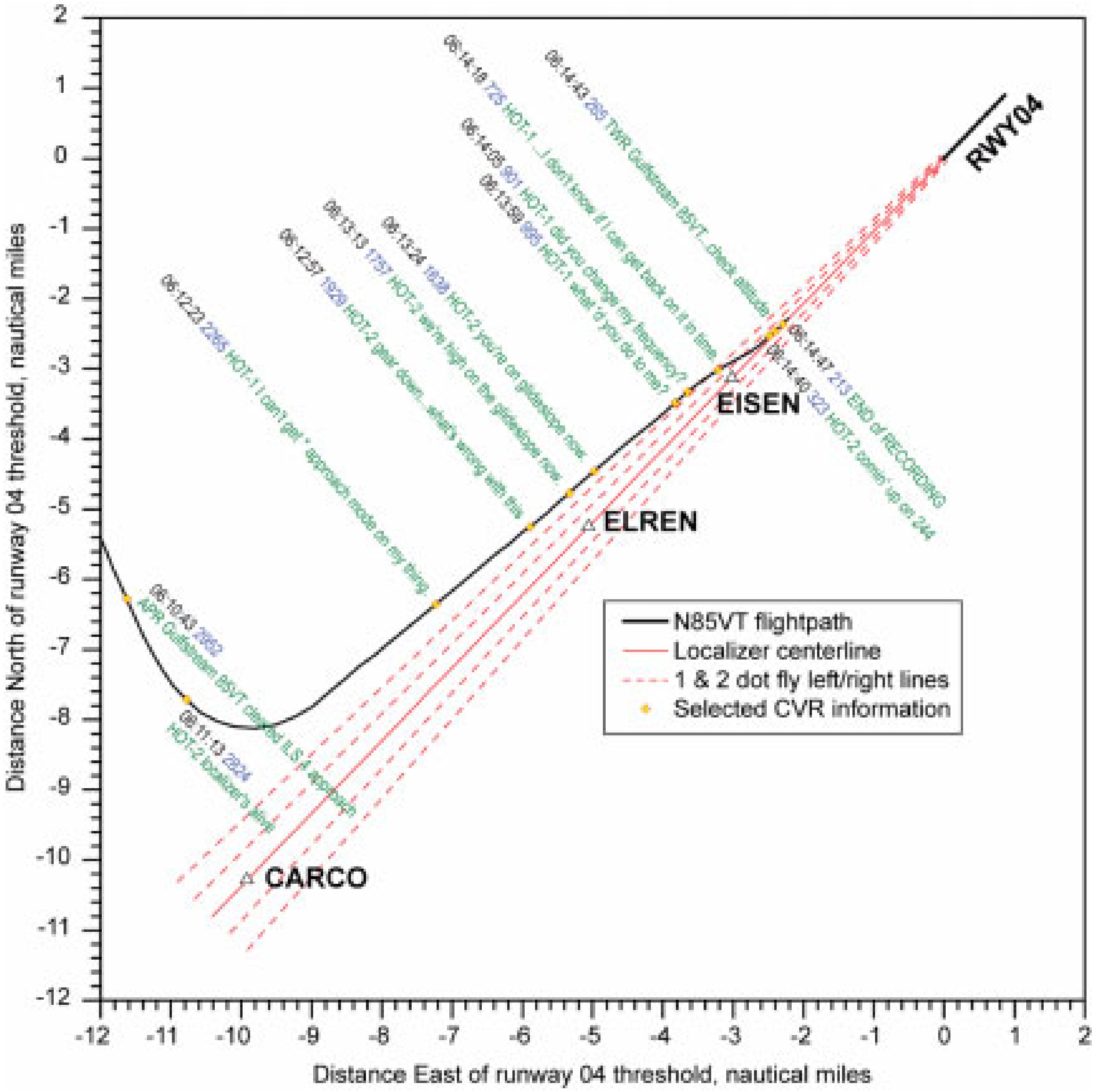

Figure 2. Accident airplane's ground track.

An airplane performance study conducted by the National Transportation Safety Board indicated that, about 0611, the airplane was descending through an altitude of about 2,900 feet on a southeasterly heading when it started turning left to converge on the ILS localizer. The airplane continued descending during the inbound turn and leveled off at an altitude of about 2,300 feet. At 0611:41, the Houston TRACON controller instructed the flight crew to contact the HOU air traffic control tower (ATCT). About 16 seconds later, the first officer contacted the HOU ATCT and stated, "with you on the ILS." The ATCT controller reported calm winds and then cleared the flight to land on runway 4. The performance study indicated that, about this time, the airplane was still at an altitude of about 2,300 feet and was located about 11 miles southwest of HOU.

At 0612:15, the captain asked the first officer to get the RVR. He then stated, "I can't get approach [APR] mode on my thing."[6] The first officer replied that he could not get the APR mode to activate either. About 0613, the airplane descended through 2,000 feet. The airplane performance study showed that the airplane was about 1,000 feet below the glideslope about this time and that the airplane remained 600 to 1,000 feet below the glideslope until impact.

At 0612:31, the HOU ATCT controller reported to the first officer that the RVR was 1,600 feet.[7] The first officer acknowledged the transmission. At 0612:40, the first officer stated, "gear down." At 0612:57, the first officer asked, "what [is]…wrong with this?" The captain responded, "I don't know." At 0613:03, the first officer further asked, "what do we have set wrong? we have…long range [navigation or NAV] or something… that we shouldn't have?" Five seconds later, the captain reported, "got NAV…VOR one." The first officer stated, "okay, we're high on the glideslope now," and the captain replied, "just gonna have to do it this way." At 0613:24, the first officer stated, "guess so. yeah you're on [the] glideslope now." However, the airplane performance study showed that, about the time that the first officer made the comments about the glideslope, the airplane was at an altitude of about 1,700 feet and was 700 feet below the glideslope. (See figure 3 for the accident airplane's altitude profile.)

At 0613:44, the captain asked the first officer if they were going to descend to an altitude of 244 feet,[8] and the first officer replied, "yeah." The airplane performance study indicated that, about 0614, the airplane was at an altitude of about 1,000 feet. At 0614:05, the captain asked, "what happened? did you change my frequency?" The first officer responded, "yeah we were down there…the VOR frequency was on." He then stated, "we're all squared away now…you got it." The captain responded, "yeah, but I, I don't know if I can get back on it in time." The first officer replied, "yeah you will…you're squared away now." The airplane performance study showed that, shortly after the captain's question regarding the frequency, the airplane turned right and subsequently intersected the ILS runway 4 localizer centerline. As shown in figure 3, about this time, the airplane was at an altitude of about 900 feet and was 800 feet below the glideslope.

[6] The airplane has an autopilot/flight director mode selector panel, and the APR mode provides flight guidance during an ILS approach.

[7] According to the published ILS runway 4 approach chart (see figure 1), the minimum allowable RVR for an ILS approach to runway 4 is 1,800 feet. Under 14 CFR Part 91 operations, pilots are allowed to initiate an approach when the reported visibility is below minimums.

[8] Two hundred forty-four feet is the decision height for the ILS runway 4 approach.

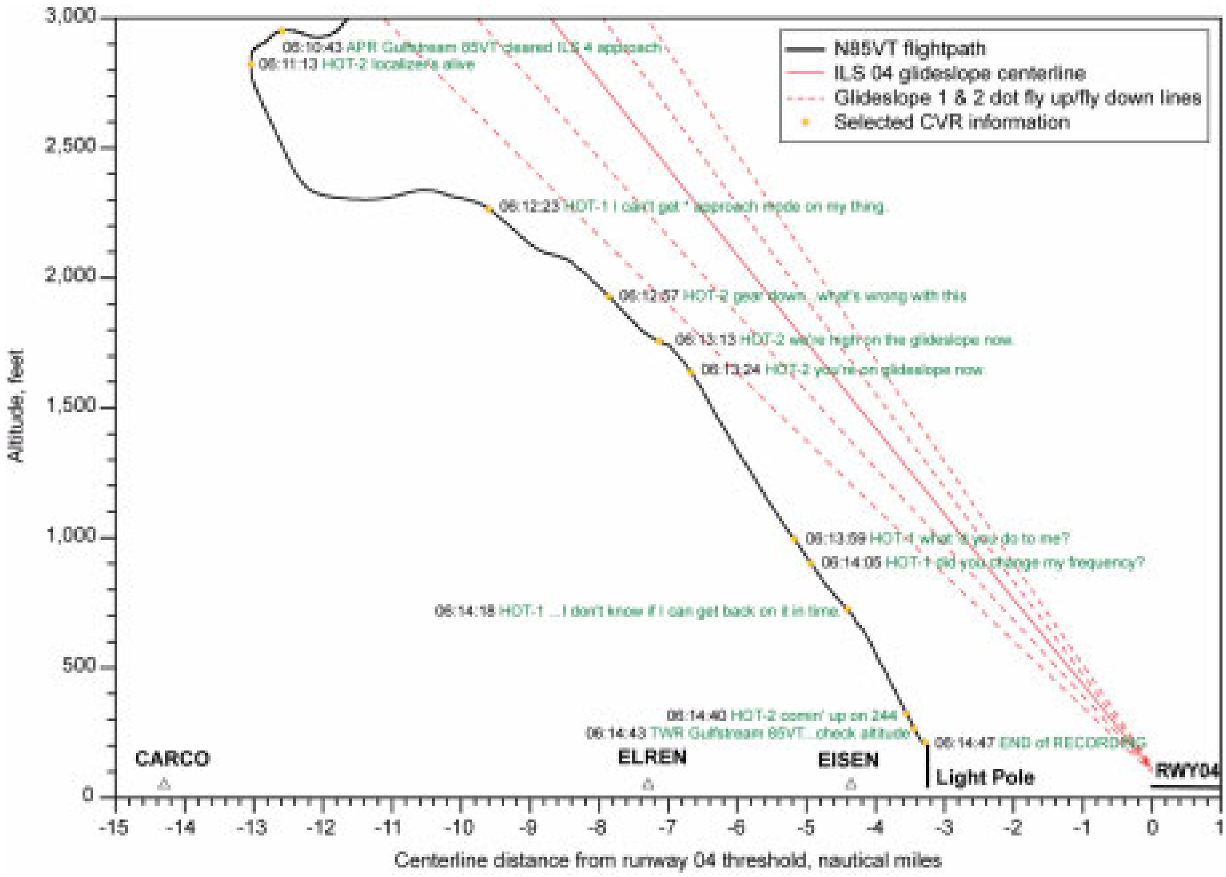

Figure 3. Accident airplane's altitude profile.

At 0614:32, the first officer stated, "I'm, I'm outside," and, 8 seconds later, he stated, "okay, comin' up on two forty four." At 0614:35, the automated radar terminal system minimum safe altitude warning (MSAW) provided visual and aural warnings to the Houston TRACON and HOU ATCT controllers. At 0614:42, the captain completed the before landing checklist, stating, "give me full flaps." At 0614:45.2, the CVR recorded the first officer state, "up," seven times in quick succession. The CVR recorded the HOU ATCT controller simultaneously state, "check your altitude, altitude indicates four hundred feet." The flight crew did not respond to the controller's transmission. No further communications were received from the flight crew.

The airplane performance study showed that the airplane tracked the ILS runway 4 localizer and continued to descend until about 0614:47. The airplane impacted a light pole at an altitude of about 198 feet and about 3 1/4 miles from the runway 4 threshold.

PERSONNEL INFORMATION

The Captain

The captain, age 67, was hired by Business Jet Services on May 1, 1998. The captain was the company's chief pilot from February 15, 2000, to July 31, 2004.[9] He held a multiengine airline transport pilot certificate with type ratings in the British Aircraft Corporation (BAC) 1-11 and the G-III. The captain received a check airman designation from the Federal Aviation Administration (FAA) effective December 10, 2002, and he was approved to conduct flight checks for Business Jet Services pilots in G-III and BAC 1-11 series airplanes. The captain's most recent FAA first-class airman medical certificate was issued on June 17, 2004, and contained the limitation that he "must wear corrective lenses." Table 1 shows the employment information reported by the captain on the application that he filled out for Business Jet Services.

Table 1. Employment information for the captain.

Employment date	Employer	Job position	Airplane type
June 1976 to July 1989	Jet Fleet Corporation, Dallas, Texas	Line captain, instructor, and check airman	BAC 1-11
August 1989 to March 1990	Flight International, Newport News, Virginia	Line captain, instructor, and check airman	BAC 1-11
April to October 1990	Self	Freelance pilot	
October 1990 to April 1998	Sky King, Inc., Sacramento, California	Captain, check airman, director of operations	BAC 1-11

Business Jet Services records indicated that the captain had accumulated about 19,000 total flight hours, 15,700 hours of which were as pilot-in-command. The captain had accumulated 1,000 hours in Gulfstream G-II and G-III airplanes, 1 hour and 55 hours of which were flown in the accident airplane in the 6 and 12 months preceding the accident, respectively. The captain had flown about 400, 90, 10, 3, and 0.75 (the accident flight) hours in the last 12 months; 90, 30, and 7 days; and 24 hours, respectively. The captain's last ground training occurred on May 18, 2004, and his last G-III proficiency check occurred on May 20, 2004.

According to the captain's wife, the captain did not work on November 20 and 21. She stated that the captain typically went to bed about 2230 to 2300 and awoke about 0800 on days that he did not work. On November 21, he awoke about 0800 and went to bed about 2100. On the morning of the accident, the captain awoke about 0220. According to a company employee, the captain arrived at DAL about 0300, and he stated that the captain looked like he had just woken up because he was "slow moving." Four company line service personnel described the captain's actions as "normal."

[9] According to the captain's wife, he retired from the chief pilot position so that he could reduce his work schedule.

The First Officer

The first officer, age 62, was hired by Business Jet Services on April 19, 2004. He was the company's chief pilot from July 31, 2004, to the accident date. He held a single- and multiengine airline transport pilot certificate with type ratings in Sabreliner N-265, Cessna Citation CE-500, Hawker Siddeley HS-125, and G-III airplanes. The first officer's most recent FAA first-class airman medical certificate was issued on September 10, 2004, and contained the limitation that he "must have available glasses for near/intermediate vision." Table 2 shows the employment information reported by the first officer on the application that he filled out for Business Jet Services.

Table 2. Employment information for the first officer.

Employment date	Employer	Job position	Airplane type
July 1974 to October 1979	Eliminator Boats, Mira Lorna, California	Chief pilot	Cessna 411 and Turbo Aerostar
October 1979 to December 1987	Ledo Financial	Flight department manager and chief pilot	Sabreliner 60, Cheyenne III, and Cessna 414
December 1987 to November 1997	Various companies	Contract pilot	Hawker Jets
November 1997 to October 2001	Elite Aviation, Van Nuys, California	Captain	G-II, G-III, and Hawker Jets
December 2001 to September 2002	XtraJet, Inc., Santa Monica, California	Captain	G-II
September 2002 to April 2004	AvJet, Burbank, California; Sun Air Jets, Camarillo, California; and XtraJet	Contract pilot	G-II, G-III, and Hawker Jets

Business Jet Services records indicated that the first officer had accumulated about 19,100 total flight hours, 17,700 hours of which were as pilot-in-command. The first officer had accumulated 1,700 hours in G-II and G-III airplanes, about 18 hours of which were flown in the accident airplane in the 8 months preceding the accident. The first officer had flown about 300, 83, 24, 8, and 0.75 (the accident flight) hours in the last 12 months; 90, 30, and 7 days; and 24 hours, respectively. The first officer's last G-III proficiency check occurred on January 25, 2004; his last line check occurred on May 20, 2004; and his last ground training occurred on May 21, 2004.

According to the first officer's wife, the first officer awoke about 0900 on November 20, 2004, and he went to bed about 2300. On November 21, the first officer awoke about 0900. The first officer's wife stated that the first officer did not have regular sleeping hours and, therefore, she was not sure exactly what time the first officer went to bed that evening; however, she thought that it was probably about 2000. According to company personnel, on the morning of the accident, the first officer arrived at DAL about 0430.[10] Two line service technicians who saw him on the morning of the accident stated that he "seemed in good spirits."

AIRPLANE INFORMATION

The accident airplane was manufactured by Gulfstream Aerospace Corporation on December 12, 1984. From October 1985 to March 1993, the airplane was operated by Jets Ejecutivos in Mexico. The FAA issued the airplane a standard airworthiness certificate on March 3, 1993.[11] The airplane was operated by five different operators from April 1993 to August 2000, when Business Jet Services bought the airplane. At the time of the accident, the airplane had accumulated about 8,566 hours.

The airplane was equipped with two Rolls-Royce Spey 511-8 turbofan engines. The time since new for the left engine was about 8,452 hours, and the time since overhaul was about 1,644 hours. The time since new for the right engine was about 8,548 hours, and the time since overhaul was about 1,648 hours.

Cockpit Instrumentation

The airplane was equipped with an electronic flight instrument system (EFIS), which consisted of two electronic displays, a symbol generator, a display controller, and a source controller. The electronic attitude director indicator (EADI) has a fast/slow indicator that is always visible and a glideslope indicator that is only visible when a valid ILS frequency has been selected. If a valid frequency has not been selected, the side of the screen where the glideslope indicator should appear remains blank. The fast/slow indicator shows airspeed guidance relative to a target airspeed, and the glideslope indicator shows aircraft vertical deviation from the ILS glideslope.

The glideslope and fast/slow indicators are the same color and about the same size. Each indicator consists of a moving pointer on a rectangular display, and each display has markers above and below the rectangle to indicate the degree of deviation. The glideslope pointer resembles a blunt-point arrow, and the fast/slow pointer resembles a rectangle (see figure 4). The accident airplane's EADI was configured with the glideslope indicator on the left side and the fast/slow indicator on the right side.[12] A review of the Safety Board's accident database revealed

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[10] The first officer's wife was not sure what time he awoke on the morning of the accident, but she indicated that he would have showered and then needed about 30 minutes to drive to the airport.

[11] During a review of company records, several documents required by Federal regulations to import and operate an airplane in the United States, including a transfer application, an export certificate of airworthiness, and a conformity and acceptance inspection record, were not found for the accident airplane. Further, no maintenance records were found for the time period that the accident airplane was operated in Mexico. Title 14 CFR 135.439 establishes the requirements for the retention of maintenance records.

[12] FAA Advisory Circular (AC) 25-11, "Transport Category Airplane Electronic Display Systems," dated July 16, 1987, provides guidance on the location of essential flight instrument displays, including the glideslope indicator. The AC recommends standardizing the location of the glideslope indicator to the right side of the main display; however, the accident airplane was manufactured before this guidance was issued. Five other company airplanes flown by the accident pilots were configured with the glideslope indicator on the left side. Of these airplanes, four had fast/slow indicators on the right side, and one had no indicator on the right side. Three of the company airplanes flown by the accident pilots had the glideslope on the right side.

no instances of accidents involving confusion of a different cockpit instrument with the glideslope indicator.

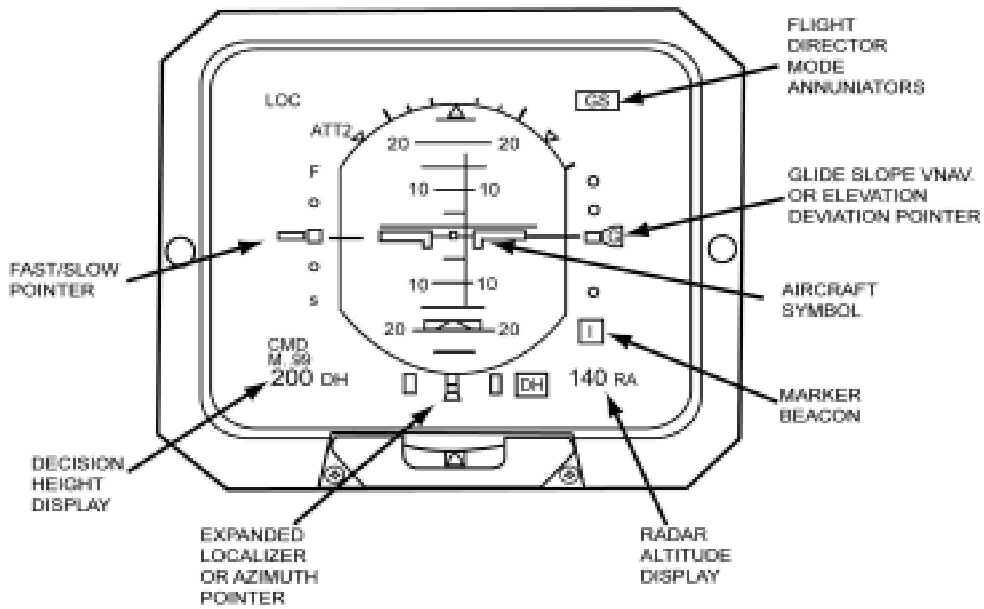

Figure 4. A diagram of the EADI.

Note: The diagram shows the glideslope and the fast/slow indicators on the right and left side of the EADI, respectively, which is opposite of the accident airplane's configuration.

The EFIS source controller is used to select attitude, heading, navigation, and bearing sources for display on the EADI. The NAV button on the source controller is used to control the source of the very high frequency (VHF) NAV information. When a frequency is entered in the VHF NAV receivers, it is stored in the standby position. The standby frequency can be activated instantly by flipping a toggle switch located next to the frequency display. The display data include the selected course and the course, localizer, and glideslope deviations.

The airplane was equipped with an autopilot/flight director mode selector panel. The APR mode is used during an ILS approach. An ILS frequency must be selected as the NAV source and valid ILS signals must be received for the APR mode to activate. When these conditions are met and the APR button is pressed, both the NAV and APR modes are armed to capture the localizer and glideslope, respectively. When the APR mode is activated, the flight director's lateral and vertical modes, including the glideslope and localizer captured and armed modes, are annunciated on the top of the EADI display. According to CVR information, neither the first officer nor the captain was initially able to activate the APR mode on their flight directors.

The airplane was equipped with an FMS that had a multifunction display (MFD), which was located on the center instrument panel and displayed navigational approach waypoints[13] that are entered into the FMS by the flight crew. As the airplane proceeds toward the airport, the displayed waypoint numbers change position on the MFD relative to a fixed airplane symbol at the bottom of the screen. An FMS does not provide the minimum altitudes for each navigational approach waypoint and supplements the airplane's other navigational guidance instruments.

Ground Proximity Warning System

The airplane was equipped with a Honeywell Mark VI ground proximity warning system (GPWS), which provides aural alerts when thresholds are exceeded in several operational modes.[14] Specifically, an aural "too low terrain" alert will be generated when the airplane reaches a specific allowable altitude for a given airspeed and the landing gear is down. Also, when a valid glideslope frequency has been selected on the captain's NAV receiver and the landing gear is down, an aural "glideslope" alert will be generated and repeated every 3 seconds if the airplane deviates below the glideslope by more than 1.3 dots and if the altitude is below 1,000 feet. The "glideslope" alert gets louder as the airplane descends below 300 feet. If a valid ILS frequency has not been selected on the NAV receiver, the "glideslope" alert is inhibited.

In addition, when the airplane descends below 500 and 200 feet and deviates below the glideslope by more than 1.3 dots and a valid ILS frequency has been selected, "500" and "200" foot aural alerts will be generated. The GPWS also generates a "minimums" alert when the airplane descends to the decision height (DH) selected by the flight crew. The CVR did not record any GPWS alerts during the accident flight.

An avionics functional check of the GPWS, which consists of a self-test and audio level check, is conducted by maintenance personnel every 12 months. The last maintenance functional check of the accident GPWS occurred on April 2, 2004, and no discrepancies were noted. According to the director of training at Business Jet Services, company pilots also perform preflight avionics functional checks. The director, who had flown a series of flights in the accident airplane during the 4 days before the accident, indicated that the airplane's GPWS tested normally during the preflight checks. He also stated that, within the last year, he had received a valid in-flight "glideslope" alert while flying low on the glideslope during a visual approach. Other company pilots who had recently flown the accident airplane reported no problems with the GPWS during the preflight checks. According to Honeywell, the only common failure that could prevent activation of the GPWS glideslope and altitude callouts is a radio altimeter failure. No evidence was found indicating that there were any problems with the radio altimeter.

METEOROLOGICAL INFORMATION

National Weather Service (NWS) surface analysis station models showed, about 0600, a low pressure area centered over northern Mexico and two frontal boundaries extended through

[13] The MFD displays a number for each approach waypoint, which indicates the waypoint's chronological order in the waypoint list.

[14] Federal regulations required that all turbine engine-powered airplanes with six or more passenger seats be equipped with an enhanced ground proximity warning system (EGPWS) by March 29, 2005. The EGPWS provides pilots with a pictorial view of terrain in addition to the aural alerts provided by the GPWS.

central and southern Texas. Station models in southeastern Texas showed that surface winds were generally less than 5 knots and that mist and light rain existed in the area.

A Terminal Aerodrome Forecast prepared by the NWS for HOU, which was valid at the time of the accident, stated, in part, the following: Wind at 100° at 5 knots, visibility 1/4 sm in fog, vertical visibility[15] 100 feet. The NWS issued a dense fog advisory at 0159 local time on November 22, which was valid at the time of the accident and warned of a large area of fog over the surrounding area and of visibility of less than 1/4 sm.

About 0245 local time, the NWS issued Airman's Meteorological Information (AIRMET) "Sierra," which covered the area surrounding the airplane's flightpath and was valid at the time of the accident. AIRMET "Sierra" warned of occasional ceilings below 1,000 feet and/or visibility below 3 sm in precipitation, mist, and/or fog. About 0455 local time, the NWS issued a convective significant meteorological information (SIGMET),[16] which covered the area near the accident site and was valid at the time of the accident. The SIGMET warned of embedded thunderstorms moving from 250° at 20 knots, with cloud tops above 45,000 feet.

Weather observations at HOU are made by an automated surface observing system (ASOS), which is located about 4 miles northeast of the accident site at an elevation of about 45 feet. ASOS transmits official meteorological aerodrome reports (METAR) 53 minutes past each hour and special weather observations (SPECI) as conditions warrant, including wind shift, visibility change, and cloud cover or height ceiling change. The 0553 METAR reported that winds were 110° at 3 knots; the tower visibility was 1/8 sm in fog; the sky condition was clouds scattered at 100 feet, broken at 600 feet, and overcast at 5,500 feet; and the surface visibility was 1/2 sm. The HOU ASOS issued SPECIs at 0605 and 0627 because the cloud ceiling had changed from scattered to broken at 100 feet and from broken to overcast at 600 feet, respectively. The HOU ASOS provides unofficial weather observations that are recorded every 5 minutes. At 0615, the HOU ASOS reported that winds were 90° at 3 knots, the tower visibility was 1/8 sm in fog, the sky condition was clouds broken at 100 feet and overcast at 600 feet, and the surface visibility was 1/2 sm.

AIRPORT INFORMATION

HOU is located about 8 miles southeast of Houston at an elevation of 46 feet. Runway 4 is equipped with a medium intensity approach lighting system with runway alignment indicator lights, high intensity runway edge lights, touchdown lights, and centerline lights. The approach end of runway 4 at HOU is equipped with a suite of sensors that measure the RVR.

Minimum Safe Altitude Warning Information

Houston TRACON provides approach control services to the HOU ATCT. Houston TRACON is equipped with an automated radar terminal system IIIA radar data processing unit

[15] Vertical visibility is defined as the vertical distance a person can see from the surface of the earth to the obscuring phenomenon.

[16] Convective SIGMETs are issued when severe thunderstorms and embedded thunderstorms occur for more than 30 minutes of the valid period, regardless of the size of the area; when a line of thunderstorms exists; or when an area of active thunderstorms affecting at least 3,000 square miles exists.

with an MSAW capability that monitors an aircraft's separation from terrain and obstacles. The MSAW warnings are provided at the TRACON and at the HOU ATCT. The MSAW operates in two modes: general terrain monitor (GTM) mode, which monitors aircraft clearance above the highest terrain and obstacles in a general area, and the approach monitor (AM) mode, which monitors aircraft clearance above terrain and obstacles within a specific area on a certain runway approach (known as the Type II Airport Area). Each of these modes alerts controllers when an aircraft is currently below or predicted to go below an established minimum safe altitude. If the minimum safe altitude thresholds are exceeded, the MSAW will provide air traffic controllers with both a visual alarm (a blinking "LA" [low altitude] on the controller's screen) and an aural alert.

A predicted monitor alert will activate if two out of three consecutive radar scans show that the aircraft will descend 100 feet below the minimum altitude within the next 15 seconds. A current monitor alert will activate if a single radar scan shows that the aircraft is below the minimum altitude. The MSAW recorded a single GTM predicted exceedance of the established minimum safe altitude of 400 feet at 0613:30, but neither of the two subsequent scans predicted that the airplane would descend below the minimum altitude; therefore, no alert was generated at this time. The MSAW recorded no AM predicted exceedances; therefore, no AM predicted alerts were generated. The MSAW generated an AM current alert at 0614:35. The HOU ATCT controller began issuing a warning to the flight crew about 7.5 seconds after the alert activated, which was about 3 to 4 seconds before impact with the light pole.

The Safety Board evaluated the airplane's flight profile and the MSAW algorithms for the HOU airport area to determine whether the MSAW provided the HOU ATCT controller the alerts expected given the design specifications of the system. The study indicated that the system performed as designed. The study also indicated that the descent profile of the accident flight was along the edge of the GTM predicted alert threshold, such that only one GTM predicted alert was recorded by the system.

During discussions with FAA staff about MSAW-related safety issues, FAA personnel noted that, in an effort to limit "nuisance alarms," MSAW parameters are presently set to not trigger an alarm for aircraft that routinely fly visual approaches lower than any precision instrument approach. Because the present MSAW design does not provide any way to alter system performance to treat aircraft flying visual approaches differently from aircraft flying instrument approaches, aircraft that deviate from instrument approach limits during IMC may not generate an MSAW alert until they are well below the expected instrument approach altitude.

On July 11, 2006, the Safety Board issued safety recommendations to the FAA that addressed MSAW alert effectiveness.[17] In its recommendation letter, the Board noted that modifying MSAW software to apply different alerting parameters to aircraft flying visual and instrument approaches will likely decrease the number of false alarms when aircraft are in visual approach conditions and increase warning times when aircraft are instrument dependent, which will increase the credibility and overall effectiveness of MSAW warnings and likely improve controllers' ability to detect hazards and potentially prevent accidents.

[17] For more information, see the Safety Board's Web site at <http://www.ntsb.gov/Recs/letters/2006/A06_44_47.pdf.>

FLIGHT RECORDERS

The accident airplane was equipped with a Fairchild model A-100 CVR. The exterior of the CVR showed no evidence of structural damage. The CVR was sent to the Safety Board's laboratory in Washington, D.C., for readout and evaluation. The interior of the CVR and the tape sustained no apparent heat or impact damage. The recording started at 0543:32 and continued uninterrupted until 0614:47. The recording consisted of two channels of "good quality" audio information, the cockpit area microphone and the combined captain and first officer audio panel information, and two channels of low level audio that was unusable.

The accident airplane was equipped with an L-3 Communications Fairchild model F1000 flight data recorder (FDR). The FDR used solid-state flash memory as the recording medium and was configured to record a minimum of 25 hours of flight data. The recorder was found to be in good condition. The FDR was sent to the Safety Board's laboratory for readout and evaluation. About 122 hours of data were recorded on the FDR, including data from the accident flight.

WRECKAGE AND IMPACT INFORMATION

The airplane impacted the top of a light pole about 198 feet above the ground. Pieces of the right wing inboard leading edge were found embedded in the joint that attaches the light fixture to the pole. Numerous pieces of the right wing inboard leading edge, upper and lower right wing skin, and the right main landing gear door were found between the light pole and the initial ground impact mark, which was about 790 feet northeast of the light pole.

The initial portion of the ground impact mark extended about 110 feet along a magnetic heading of 035°. Numerous pieces of the left wing outboard leading edge were found embedded in the ground along the gouge mark. The left wing tip was found near the gouge mark about 50 feet from the initial ground impact mark. The airplane's main wreckage, which contained the majority of the airplane's forward fuselage and cockpit, was found beyond the ground impact mark. All of the airplane structure, including the fuselage, wings, and empennage, were found along the wreckage path.

Both engines were found separated from the airplane. The engines showed no indications of uncontainment, case rupture, or in-flight fire. The left engine low pressure compressor blades were found in place and bent opposite the direction of rotation. The right engine low pressure compressor blades were found in place and straight, with no circumferential rub marks. Postaccident disassembly of the engines revealed no preexisting defects or malfunctions, and testing of both engines' fuel controls showed that they were functioning normally.

MEDICAL AND PATHOLOGICAL INFORMATION

Tissue and fluid specimens from both pilots tested negative for a wide range of drugs, including major drugs of abuse. The captain's specimen tested positive for ethanol, but the analysis indicated that the detected ethanol most likely resulted from postmortem formation.

TESTS AND RESEARCH

Flight simulations were conducted to determine whether any GPWS alerts would have been expected during the flight with parameters, such as altitude, airspeed, and glideslope deviation, set to approximate the conditions of the accident flight profile. The simulations showed that the airplane penetrated the descent-below-glideslope alert envelope at an altitude of about 925 feet, by which time, the ILS frequency had been selected by the first officer and the landing gear commanded down. The airplane penetrated the insufficient terrain clearance alert envelope at an altitude of about 255 feet. Therefore, the "glideslope" and "too low terrain" alerts, respectively, should have activated. The simulations also showed that the "500" and "200" feet aural alerts should have activated.

Postaccident tests using an engineering bench test unit were also conducted to verify whether GPWS alerts would be generated with parameters set to approximate the accident flight profile. The tests showed that, at an altitude about 915 feet, the "glideslope" alert sounded and repeated. During the tests, the altitude was continually reduced, and the following was noted: about 500 feet, the "500" foot alert sounded; about 300 feet, the "glideslope" alert got louder; about 272 feet, the "too low terrain" alert sounded and repeated; about 244 feet, the "minimums" alert sounded; and, about 200 feet, the "200" foot alert sounded.

ORGANIZATIONAL AND MANAGEMENT INFORMATION

Business Jet Services is an aviation management company that specializes in management services for corporate aircraft owners and provides Part 135 on-demand charter services worldwide. At the time of the accident, the company had about 100 employees, including 35 Part 135 pilots, and a fleet of 13 airplanes, 7 of which were Gulfstreams.

Instrument Precision Approach and Landing Guidance

According to Business Jet Services' Gulfstream III Standard Operating Procedures (SOPs), after the flight crew reviews the descent procedures, the flying pilot is required to brief the approach, including the airplane configuration (such as the flap setting) and the final approach fix (FAF) altitude. The SOPs state that as many checklist items as possible should be accomplished and that the approach checklist must be completed before the initial approach fix. The CVR recorded the first officer accomplishing the approach briefing; however, the CVR did not record him mentioning the airplane's configuration or the FAF altitude, which was 1,500 feet.

The SOPs also indicate that, at initial convergence of the localizer, the flying pilot is required to call out, "localizer alive," and, at initial downward needle movement of the glideslope indicator, to call out, "glideslope alive." Further, the flying pilot is required to call out, "one dot to go," when the airplane is one dot below the glideslope; "localizer captured," when the annunciator indicates that the localizer has been captured; and, "glideslope captured," when the annunciator indicates that the glideslope has been captured. CVR evidence indicates that the first officer called out, "localizer alive," but that he did not call out, "glideslope alive," or, "one dot to go." The CVR transcript indicates that the first officer made the first glideslope-related callout at 0613:14, when he stated, "we're high on the glideslope."

The SOPs also state that, no later than the FAF crosscheck, the nonflying pilot should tune the VHF NAV receivers to a specific frequency and then identify and monitor the frequency.[18] The nonflying pilot is also required to call out when the airplane is 1,000, 500, 200, and 100 feet above the DH and when the localizer and glideslope deviate one dot or more. The CVR transcript indicated that, although the first officer tuned the VHF frequency in the standby position earlier in the flight, he did not switch the VHF NAV receivers from the HUB VOR frequency to the ILS frequency until the airplane was at an altitude of about 1,000 feet nor did he identify or monitor the frequency. Further, the CVR did not record either pilot making any altitude or deviation callouts.

Business Jet Services' stabilized approach criteria require that, within 500 feet of the touchdown elevation, the airplane must be within the approach window, which requires, in part, that the glideslope and the localizer must not deviate more than one dot and that the descent rate must be less than 1,000 feet per minute (fpm). If the airplane is not within these criteria, the nonflying pilot should call out, "missed approach," and a go-around should be executed. According to the Safety Board's airplane performance study, about the time that the airplane was at an altitude of about 500 feet, the glideslope display would have shown a deviation of more than one dot and the descent rate would have exceeded 1,000 fpm. The CVR did not record either pilot call for a missed approach or initiate a go-around.

Maintenance Records

During a review of Business Jet Services maintenance inspection records, Safety Board investigators noted several discrepancies, including missing inspector signoffs, missing stamps and dates of maintenance actions, and other missing information. Many of the Form 337s, which are used to document major repairs and alterations, noted that they were approved by the Oklahoma City Flight Standards District Office (FSDO); however, no approving documentation was attached to the forms. In addition, although several records were found indicating compliance with airworthiness directives (AD), in many of these cases, no records were found pertaining to work accomplished for compliance with the ADs.

Federal Aviation Administration Surveillance

Business Jet Services was initially certificated on July 24, 1998, by the Dallas FSDO. On March 15, 2000, the company's operating certificate was transferred to the Oklahoma City FSDO. The Business Jet Services principal maintenance inspector (PMI), who was based in Oklahoma City, had been in that position since 2000. The PMI was also responsible for the surveillance of three other Part 135 operators, four repair stations, one flight school, and one airplane and powerplants school.

A review of the FAA's Program Tracking and Recording Subsystem records indicated that, from January to November 2004, the PMI visited Business Jet Services 15 times and accomplished all of the required surveillance items, which included a maintenance records review

[18] To identify a frequency, the nonflying pilot listens for a specific, audible Morse-code pattern, which is received by the VHF NAV receivers.

on May 6, 2004. No maintenance procedures or record-keeping discrepancies were noted by the PMI in the FAA's records.

Safety Recommendation A-05-08

As a result of the June 13, 2003, Air Sunshine, Inc., flight 527 accident, the Safety Board issued Safety Recommendation A-05-08, which asked the FAA to do the following:

> Review the procedures used during its oversight of Air Sunshine, including those for the Surveillance and Evaluation Program [SEP] and Regional Aviation Safety Inspection Program, to determine why the inspections failed to ensure that operational and maintenance issues that existed at the company were corrected. On the basis of the findings of this review, modify Part 135 inspection procedures to ensure that such issues, including maintenance record-keeping and practices, are identified and corrected before accidents occur.[19]

In response to the safety recommendation, the FAA indicated that it will review and revise FAA Order 8300.10, "Airworthiness Inspector's Handbook," to enhance inspectors' awareness of inadequate record-keeping systems and the timely correction of record-keeping discrepancies. The FAA noted that because the SEP was designed and used for Part 12l operators, it was not applicable to Air Sunshine. The FAA stated that FAA Order 1800.56, "National Flight Standards Work Program Guidelines," provided guidelines for the establishment of a surveillance work program. Pending the FAA's revisions to Order 8300.10, Safety Recommendation A-05-08 was classified "Open—Acceptable Response," on January 18, 2006.

ADDITIONAL INFORMATION

FAA Order 7110.65, "Air Traffic Control," states that approach controllers are required to issue the current touchdown RVR for the runways in use when the prevailing visibility is 1 mile or less or when the RVR indicates a reportable value (an RVR that is fewer than 6,000 feet). FAA Order 7110.65 also states that approach "controllers shall ensure that pilots receive the most current pertinent weather information. Ask the pilot to confirm receipt of the current ATIS information if the pilot does not initially state the appropriate ATIS code." The CVR did not record the Houston TRACON controller question the first officer when he stated that he had ATIS information "Kilo" instead of information "Quebec"; notify the flight crew of the current ATIS, which at that time was information "Romeo"; or provide the flight crew with the current RVR.

[19] For more information, see the Board's Web site at <http://www.ntsb.gov/Recs/letters/2005/A05_08_10.pdf.>

ANALYSIS

General

The flight crew was performing an instrument precision approach; therefore, the presence of low cloud ceilings and reduced visibility should not have affected the pilots' ability to fly the approach.

The Houston TRACON controller did not correct the first officer when he stated that he had ATIS information "Kilo" instead of "Quebec"; confirm that the flight crew had the most current weather, ATIS information "Romeo," and RVR; or question the first officer when he read back the incorrect runway assignment,[20] as required by FAA Order 7110.65. However, because the RVR and weather conditions had not changed considerably since the time the first officer received the information and the CVR recorded the flight crew correctly reference the runway later in the approach, the controller's errors did not contribute to the accident.

Postaccident benchtests set to parameters approximating the accident flight profile showed that the "glideslope," "500" foot, "too low terrain," "minimums," "300" foot, and "200" foot GPWS alerts should have activated on the accident flight. However, the CVR did not record the accident GPWS generate any alerts during the flight. The only common failure that could prevent activation of the GPWS glideslope and altitude callouts is a radio altimeter failure. However, a review of Business Jet Services' maintenance records and the CVR transcript found no evidence indicating any problems with the radio altimeter. The GPWS unit and the radio altimeter were destroyed during impact; therefore, the Safety Board was unable to determine why the GPWS did not operate as expected. Federal regulations would have required that the accident airplane be equipped with an EGPWS by March 29, 2005. The EGPWS provides pilots with a pictorial view of terrain in addition to aural alerts.

A review of the FAA's Program Tracking and Reporting System records indicated that the PMI reviewed company maintenance records, which is a required inspection item, on May 6, 2004, and no discrepancies were noted. However, a Safety Board review of the company's maintenance records revealed that some of the maintenance paperwork was inconsistent, incomplete, and/or not documented properly. The Board is concerned that, although the FAA PMI's oversight of Business Jet Services was in accordance with standard guidelines, the PMI did not detect the maintenance records deficiencies found during the investigation. As noted previously, the Safety Board addressed this issue by issuing Safety Recommendation A-05-08, which is currently classified "Open—Acceptable Response," pending the FAA's revisions to Order 8300.10.

Accident Sequence

The examination of CVR and FDR data indicated that the en route portion of the accident flight from DAL to HOU was routine. The first officer started the approach briefing about 0547:50. However, Business Jet Services' SOPs state that the flying pilot—in this case, the

[20] At 0559:06, the CVR recorded the first officer read back "runway one four" instead of "runway four."

captain—should brief the approach. Further, during the briefing, the first officer did not mention all of the approach checklist items, including the FAF altitude.

About 3 minutes after starting the approach briefing, the CVR recorded the captain asking the first officer to set the navigational approach waypoints in the FMS. The pilots then discussed deleting the HUB VOR waypoint from the list, which the first officer most likely did at that time. The MFD only displays a chronological number for each approach waypoint; therefore, it is possible that the flight crew forgot that the first officer removed the HUB waypoint from the FMS, causing them to mistakenly believe that the last waypoint displayed on the MFD (EISEN) was the airport. Regardless, an FMS serves as a secondary navigational aid on an ILS approach. The pilots should have been relying on the primary navigational aids during the approach.

About 0612, the CVR recorded both pilots stating that they were unable to get the APR mode on their flight directors to activate. About 1 minute later, the first officer told the captain that they were "high on" the glideslope and then that they were "on" the glideslope. According to the airplane performance study, the airplane was actually about 700 feet below the glideslope when the first officer made these statements, and the airplane remained well below the glideslope throughout the rest of the approach. Although the first officer entered the ILS frequency in the standby position in both VHF NAV receivers earlier in the approach (about 0559, after the approach clearance), at this point in the approach, neither pilot had selected the ILS frequency. Further, the glideslope indicator would not have been visible on the EADI. Therefore, the first officer could not have been looking at the glideslope indicator when he made the statements about the glideslope.

The first officer's failure to activate and identify the ILS frequency earlier in the approach prevented the flight crew from recognizing that the airplane was off course and below the glideslope. The fast/slow indicator on the EADI resembles the glideslope indicator and is visible on the EADI at all times, whereas the glideslope indicator only appears on the screen once an ILS frequency has been activated. Postaccident flight simulations revealed that the fast/slow indicator would have been centered within one dot during the approach sequence and that the indications would have been consistent with the first officer's comments about the glideslope if he had mistaken the fast/slow indicator for the glideslope indicator.

The first officer did not switch the VOR frequency to the ILS frequency until about 1 minute before impact. When the first officer realized that he had not switched to the ILS frequency, he should have called for a missed approach because the airplane was not properly configured for the approach and was not receiving proper vertical guidance during the most critical phase of the flight. Once the first officer selected the ILS frequency, the glideslope indicator would have appeared on the screen and both pilots' displays would have shown a full-scale deviation below the glideslope and a full-scale or near full-scale deviation of the localizer; however, the CVR did not record either pilot mention the glideslope deviation. The fast/slow indicator would have remained visible on the EADI even after the ILS frequency was selected, which may explain why the pilots did not immediately notice the glideslope indicator deviation after the first officer selected the ILS frequency. Therefore, the pilots most likely mistook the fast/slow indicator for the glideslope indicator throughout the approach sequence.

The Safety Board is concerned that the first officer switched the frequency of a primary navigational aid and failed to inform the captain. If the pilot-not-flying takes such actions without first checking with or simultaneously informing the flying pilot, confusion can occur, as evidenced by the captain's remark, "What happened? Did you change my frequency?" In this case, because the airplane was at such a low altitude (about 1,000 feet) in IMC, such a major change should have prompted the captain to immediately initiate a missed approach.

Shortly after activating the ILS frequency, the first officer stated, "we're all squared away now." The captain replied, "I don't know if I can get back on it [the ILS localizer] in time." The first officer stated, "yeah you will. you're squared away now." These comments indicate that the pilots were focused on correcting the localizer deviation. The first officer dismissed the captain's concerns, and the captain did not proceed to assert his authority. As noted, earlier in the approach, the flight crew had attempted unsuccessfully to activate the flight director APR mode, and no evidence indicates that either pilot tried to reactivate the APR mode on their flight directors once the ILS frequency was selected. Therefore, the flight crew continued to perform the approach without the advantage of flight director guidance. The CVR did not record the pilots making any of the required altitude callouts, except at 0614:40, when the first officer announced that they had reached the DH of 244 feet. The airplane hit the light pole immediately thereafter.

FDR data show that the airplane exceeded a descent rate of 1,000 fpm within 500 feet of the touchdown elevation, which was outside of the stabilized approach window. In addition, although the localizer deviation was less than one dot by the time the airplane reached 500 feet, the localizer would have shown a full-scale or near full-scale deviation of the localizer when the first officer initially activated the ILS frequency. Both of these factors should also have prompted the flight crew to initiate a missed approach.

Throughout the approach, the flight crew failed to follow approved company approach procedures. The first officer's failure to activate and identify the ILS frequency at the appropriate point in the approach prevented the pilots from receiving glideslope and localizer information on their EADIs until late in the approach. Further, the pilots' failure to engage the APR mode on their flight directors after the ILS frequency was selected prevented them from receiving flight director guidance. In addition, neither pilot was adequately scanning the cockpit instruments. Compliance with standard company procedures, activating and identifying the ILS frequency and subsequently the APR mode, and adequate monitoring of the flight instruments would likely have prevented the accident.

Fatigue might have also played a role in the flight crew's degraded situational awareness. According to the captain's wife, on the night before the accident, the captain received about 4 hours less sleep than normal. A company employee stated that, when the captain arrived for work on the morning of the accident, he looked as though he had just woken up. The first officer's wife stated that the first officer did not have regular sleeping hours and that she was not sure how much sleep he got the night before the accident. Although the early reporting time for the accident flight might have resulted in flight crew fatigue, the actual amount and quality of sleep received by the captain and the first officer could not be determined. Regardless, their improper conduct of the approach reflected fundamental operational shortcomings that were independent of fatigue.

Minimum Safe Altitude Warning Operation

The Safety Board evaluated the airplane's flight profile and the MSAW algorithms for the HOU airport area and determined that the MSAW performed as designed given the alert thresholds established for the HOU airport area. The study determined that the accident descent profile was along the edge of the MSAW GTM predicted alert threshold. In this case, although the MSAW recorded a single predicted exceedance of the threshold at 0614:30, the two subsequent scans did not predict exceedances; therefore, no GTM predicted alert was generated.

The MSAW generated an AM current alert at 0614:35. The HOU ATCT controller began issuing a low-altitude warning to the flight crew about 7.5 seconds later. Analysis of the MSAW's performance found that the system provided only about 11.5 seconds of warning time before the airplane struck the light pole, which was not sufficient time for the controller to recognize the alert and warn the flight crew in time to prevent the accident. Configuring a single set of MSAW parameters is a balancing act between minimizing "nuisance alarms" and providing sufficient warning time. Implementing software and adaptation modifications to minimize or eliminate unwarranted MSAW alerts without degrading the usefulness and safety benefit of MSAW will increase the credibility and overall effectiveness of MSAW warnings. Such modifications will likely improve controllers' ability to detect hazards and potentially prevent controlled flight into terrain accidents. As noted previously, in July 2006, the Safety Board issued safety recommendations to the FAA that addressed MSAW alert effectiveness.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to adequately monitor and cross-check the flight instruments during the approach. Contributing to the accident was the flight crew's failure to select the instrument landing system frequency in a timely manner and to adhere to approved company approach procedures, including the stabilized approach criteria.

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