FLIGHT SAFETY FOUNDATION
Accident Prevention
Vol. 56 No. 6 *For Everyone Concerned with the Safety of Flight* June 1999

Learjet Strikes Terrain When Crew Tracks False Glideslope Indication and Continues Descent Below Published Decision Height

The U.S. National Transportation Safety Board said that the flight crew did not follow standard operating procedures while conducting an instrument landing system approach. The investigation prompted the board to recommend acceleration of a proposed schedule for requiring installation of terrain awareness and warning systems in all turbine airplanes with six or more passenger seats.

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FSF Editorial Staff

On Jan. 13, 1998, a Gates Learjet 25B struck terrain approximately two nautical miles (3.7 kilometers) from the runway threshold during the flight crew's second instrument landing system (ILS) approach to Runway 26 at George Bush Intercontinental Airport (KIAH) in Houston, Texas, United States.

The first ILS approach had resulted in a missed approach because the flight crew had a problem with the compass card in the captain's horizontal situation indicator (HSI).

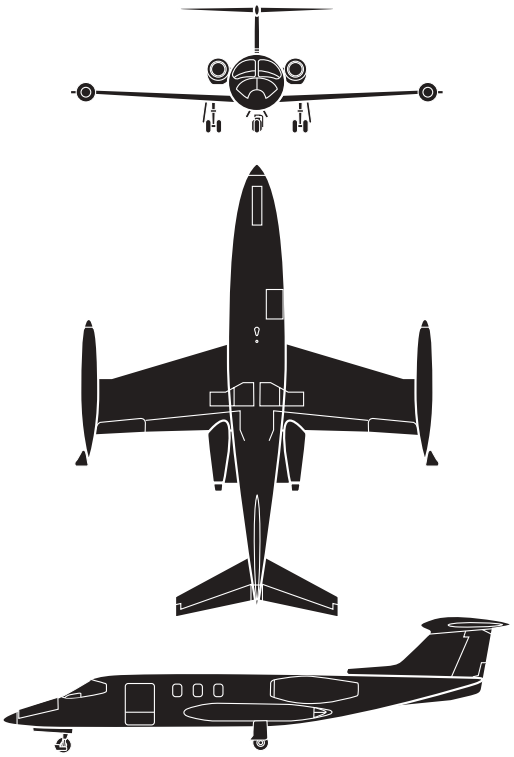
During the second ILS approach, the captain had difficulty tracking the localizer and transferred control to the first officer when the airplane was inbound from the outer marker on the final approach course. The first officer's HSI and attitude director indicator (ADI) provided false fly-down glideslope indications. The Learjet was flown below the published decision height and struck trees and terrain. Both pilots were killed.

The final report by the U.S. National Transportation Safety Board (NTSB) said, "The probable cause of this accident was the flight crew's continued descent of the airplane below the glideslope and through the published decision height without visual contact with the runway environment.

"Also, when the captain encountered difficulty tracking the localizer course, his improper decision to continue the approach by transferring control to the first officer, instead of executing a missed approach, contributed to the cause [of the accident]."

The report said that other contributing factors were:

- "[The operator's] failure to provide an airworthy airplane to the flight crew following maintenance, resulting in a false glideslope indication to the first officer;
- "The flight crew's failure to follow company crew-coordination procedures, which called for approach briefings and altitude callouts; [and,]
- "The lack of an FAA [U.S. Federal Aviation Administration] requirement for a ground-proximity warning system on the airplane."



Gates Learjet 25B

William P. Lear's light twin-engine business jet, the Learjet 23, was first flown in 1963. The eight-seat airplane was certified under U.S. Civil Air Regulations Part 3, the airworthiness standards for normal-category airplanes. In 1966, the Learjet 23 was replaced by the Learjet 24, and the 10-seat Learjet 25 was introduced. The Learjet 24 and Learjet 25, and all subsequent models, were certified under U.S. Federal Aviation Regulations Part 25, the airworthiness standards for transport-category airplanes. William P. Lear sold his interests in Lear Jet Corp. in 1967 to Gates Rubber Co., which changed the company name to Gates Learjet.

The Gates Learjet 25B, introduced in 1970, featured several refinements. The airplane has General Electric CJ610-6 turbojet engines, each rated at 2,950 pounds (1,338 kilograms) thrust. A maximum of 6,057 pounds (2,748 kilograms) of fuel can be carried in wing-tip tanks, internal wing tanks and a fuselage tank. Range with maximum fuel and a 45-minute fuel reserve is 1,759 nautical miles (3,258 kilometers). Maximum takeoff weight is 15,000 pounds (6,804 kilograms). Maximum landing weight is 13,300 pounds (6,033 kilograms). Maximum rate of climb at sea level is 5,600 feet per minute (1,708 meters per minute). Maximum single-engine rate of climb at sea level is 1,600 feet per minute (488 meters per minute). Maximum cruising speed at 41,000 feet is 473 knots (876 kilometers per hour).

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

The airplane was manufactured in 1974 and had accumulated 8,913 flight hours before a major (600-hour) inspection was completed on Aug. 31, 1997. The operator, American Corporate Aviation of Houston, said that the airplane had been flown for 30 hours after the inspection.

American Corporate Aviation obtained an air-carrier certificate from FAA in 1968. On March 12, 1994, a company airplane with five people aboard was involved in an accident during an air-ambulance flight in Phoenix, Arizona.

"The airplane [a Rockwell Commander 681] sustained substantial damage during landing with the [main landing gear] partially extended," said the report. "The pilot, two flight nurses and two passengers were not injured. [NTSB] determined that the probable cause of the accident was 'the failure of the hydraulic [system pressure lines] and nitrogen system pressure lines, due to an inadequate maintenance-inspection program, which failed to detect the [corroded] condition of the lines.'"

At the time of the Learjet accident, the company was authorized by FAA to conduct U.S. Federal Aviation Regulations (FARs) Part 135 on-demand operations in nine airplane types. The report said that the Learjet was to be flown on a Part 91 positioning flight from William P. Hobby Airport (KHOU), which is eight statute miles (13 kilometers) southeast of Houston, to KIAH, which is 15 statute miles (24 kilometers) north of Houston. The flight crew was to board five passengers at KIAH for a Part 135 flight to Fargo, North Dakota. A return trip was to be conducted later in the day.

The report said that American Corporate Aviation denied that it had operational responsibility for the flight. "The CEO [of American Corporate Aviation] stated that he 'assumed' the trip was [a FARs] Part 91 flight for Linrose Aviation [of Longview, Texas,] because he 'knew' the captain worked for Linrose Aviation," said the report. "The CEO said that he proposed trading the flight time on the Fargo trip for future flight time on Linrose Aviation's Learjet [which had FAA authorization for Part 135 operations by American Corporate Aviation]." Nevertheless, the report referred to American Corporate Aviation as the operator of the Learjet on the day of the accident.

The captain, 52, had an airline transport pilot certificate and type ratings for the Learjet, the Hawker Siddeley HS-125 and the Israeli Aircraft Industries Westwind. He had 8,777 flight hours, including 2,512 flight hours in the Learjet, and had flown 610 hours in the year preceding the accident.

The report said that the captain's logbook showed that he had conducted one previous flight in the accident airplane on Dec. 23, 1997, and he had logged 6.9 flight hours.

"The captain's most recent Learjet recurrent simulator training was accomplished in October 1997 at the facilities of SimuFlite Training International," said the report. "The training consisted of 12 hours of ground school and nine hours of flight-simulator time."

The captain was working as a contract pilot for three Part 135 operators in the Houston area: American Corporate Aviation, Aviex Jet and Executive Air Charter. The captain was employed

by Linrose Aviation from July 1997 to December 1997 as a Learjet 25D pilot-in-command.

The report said, "According to the vice president of Linrose Aviation, the captain's employment was terminated because of his failure to follow company rules and not because of unsatisfactory flying skills."

The report said that pilots and check airmen who had flown the Learjet with the captain described the captain as an experienced pilot with an outgoing, friendly personality.

"Comments concerning the captain's flying skills were generally favorable," said the report. "However, the check airman for Aviex Jet stated that the captain was 'well above average, but not the best in pilot skills.'"

The first officer, 39, had a commercial pilot certificate, a flight instructor certificate and a Douglas DC-3 type rating. She had 2,237 flight hours, including 35 flight hours in the Learjet, and had flown 597 hours in the year preceding the accident.

The first officer was working as a contract pilot and as a part-time flight instructor. The report said that she had completed training requirements and testing requirements to serve as a Learjet second-in-command for American Corporate Aviation, Air America Jet Charter and Aviex Jet.

"Her initial Learjet simulator training was accomplished in April 1997 at the facilities of FlightSafety International," said the report. "This training consisted of 14 hours of ground school and 18 hours of flight-simulator time."

The report said that captains and check airmen who had flown the Learjet with the first officer described her as a hard worker with a strong desire to improve her knowledge of the airplane and to obtain a Learjet type rating.

"Regarding the first officer's piloting skills, comments by captains included: 'for a low-time pilot (she) did a pretty good job' and '(she) flew like she was ready to get her Learjet type rating,'" said the report. "However, the check airman for Aviex jet stated that the first officer 'was at minimum proficiency and capability.' The check airman believed that the first officer was not 'cut out to be a charter pilot,' [and said] that 'her biggest problem was basic hand-eye coordination. She was easily overloaded. She would be fine if she were paired with a strong pilot-in-command.'"

The report said that the first officer's logbook indicated that she had conducted six previous flights, totaling 21.4 flight hours, in the accident airplane; the most recent flight was conducted on Dec. 24, 1997.

The report said, "Neither the captain nor the first officer had any [FAA] record of airplane accidents, incidents or enforcement actions. Interviews with immediate family members and acquaintances disclosed no evidence of any activities that would have prevented either flight crewmember from obtaining sufficient rest in the 72 hours before the accident."

On the day of the accident, a cold front moved south through Texas and Louisiana. That morning, Houston was south of the front and in an extensive area of fog, mist, scattered rain showers and scattered thunderstorms.

The captain telephoned a flight service station (FSS) at 0528 local time. He filed instrument-flight-rules flight plans for the flights from KHOU to KIAH and from KIAH to Fargo. The estimated departure time from KHOU was 0645, and the estimated flight time from KHOU to KIAH was 10 minutes.

The captain said, "Tell me how bad the weather is. I know it is foggy as a son-of-a-gun."

The FSS specialist said, "Yeah, it really is. You may have some problem getting in to [KIAH]." The specialist said that KHOU had one-eighth-mile (0.2-kilometer) visibility and "zero vertical visibility," and that KIAH had one-quarter-mile (0.4-kilometer) visibility and 100 feet (30.5 meters) of vertical visibility. The forecast for both airports was for weather conditions to improve to one-half-mile (0.8-kilometer) visibility and a 200-foot ceiling by 0700, and to four miles (6.4 kilometers) visibility and a 1,000-foot ceiling by 0900. The forecast for Fargo was for unrestricted visibility and scattered clouds at 12,000 feet.

The captain said, "I'm just going to take my time and mosey on out to the airport. After it gets a little better, I'll get an update with you. Then we'll go."

The captain called the FSS three more times — at 0611, at 0645 and at 0705. During the 0705 briefing, he was told that KIAH had one-quarter-mile visibility, a 100-foot overcast ceiling and a thunderstorm near the airport.

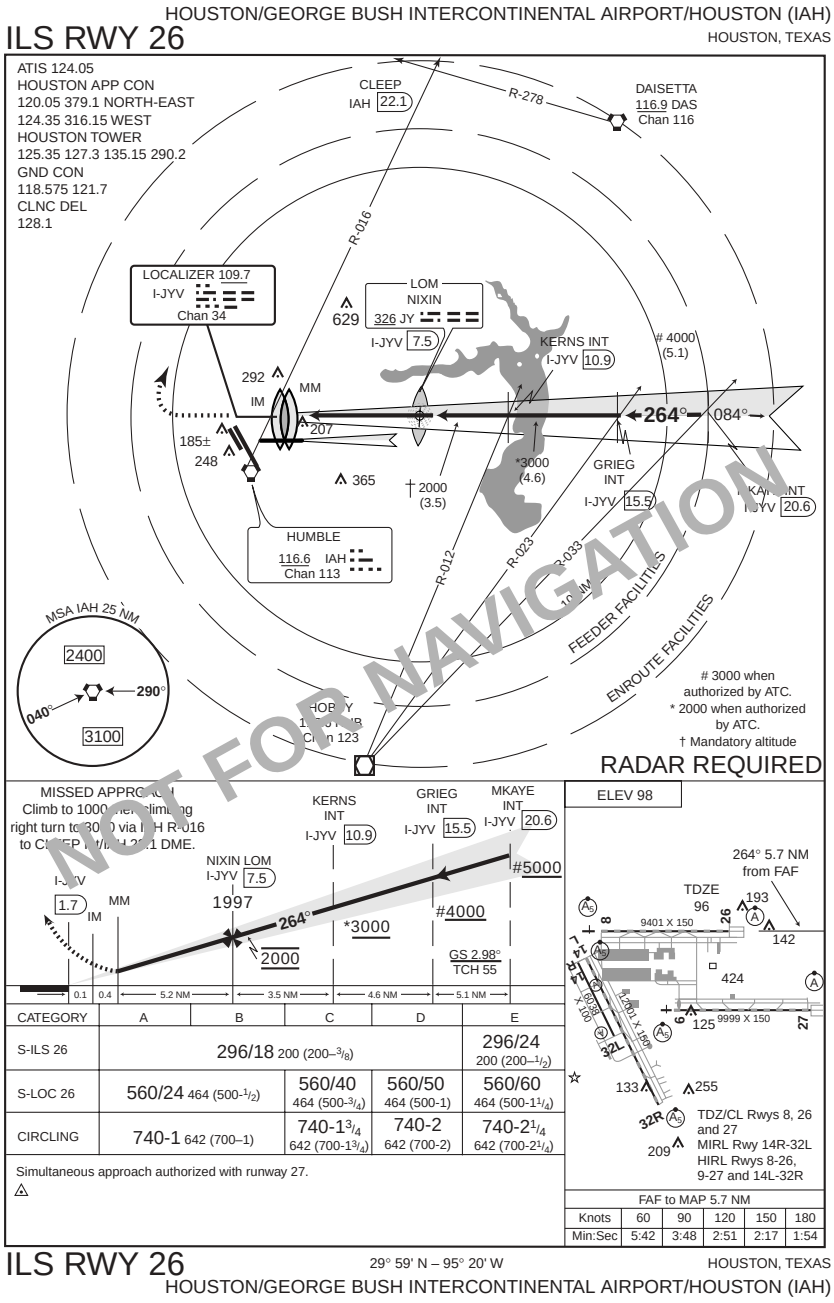
The captain said, "I cannot get in there. … So, I'll just wait a little while and call you back."

Figure 1 (page 4) shows that the published minimum visibility for the ILS approach to Runway 26 at KIAH was 1,800 feet runway visual range (RVR); the decision height was 296 feet, or 200 feet above the runway touchdown zone.

The captain did not call the FSS after the 0705 briefing. The flight crew took off from KHOU at 0745 and flew the airplane to 3,000 feet. The departure controller told the crew that simultaneous approaches were being conducted to Runway 26 and to Runway 27 at KIAH, and to expect clearance for the ILS approach to Runway 26.

The departure controller told the crew that weather conditions in the current automatic terminal information service broadcast included surface wind from 340 degrees at seven

Instrument Landing System Runway 26 Approach, George Bush Intercontinental Airport, Houston, Texas, United States Jan. 13, 1998



Note: Typefaces, symbols and placement of information may not be identical to official approach chart.

Source: U.S. National Transportation Safety Board and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service

Figure 1

knots (13 kilometers per hour [kph]), visibility of one-half mile in mist, broken ceilings at 200 feet and 600 feet, an overcast at 900 feet, and more than 6,000 feet RVR on Runway 26.

The flight crew did not follow the instrument-approach crew-coordination procedures in the operator's training manual. The procedures require the captain to set the appropriate frequencies and bearings on the navigation equipment, and to conduct an approach briefing. The procedures require the first officer to review the approach after the captain completes the approach briefing and, while the approach is being conducted, to announce glideslope interception and to announce the

following heights above the minimum descent altitude or missed approach point (decision height): 1,000 feet, 500 feet, 400 feet, 300 feet, 200 feet and 100 feet. The procedures also require the first officer to announce arrival at the missed approach point and "runway in sight," if applicable.

According to recorded cockpit voice recorder (CVR) data, at 0748:15, the first officer said, "All right, I'm gonna set you up for the ILS. … One oh nine point seven … and it's uh, two six four." (The localizer frequency was 109.7 MHz, and the final approach course was 264 degrees.)

The captain said, "Why don't you put me on the ILS, I guess."

The first officer said, "Yeah, he's gonna vector you around. … Your airport's over this way, and your ADF [automatic direction finder] as well … OK, takeoff … take your strobes off out here … Altimeters are set and I'll get you a ref speed. We'll be about thirteen, three, that's the legal limit." The first officer then said that the reference speed was 124 knots (230 kph).

Figure 2 shows the airplane's ground track. At 0749:49, the approach controller told the crew to descend to 2,000 feet and to turn left to a heading of 360 degrees. At 0751:43, the approach controller told the crew to turn to a heading of 280 degrees, advised that the airplane was four miles from the final approach fix and cleared the crew for the approach. At 0752:51, the KIAH tower controller cleared the crew to land on Runway 26.

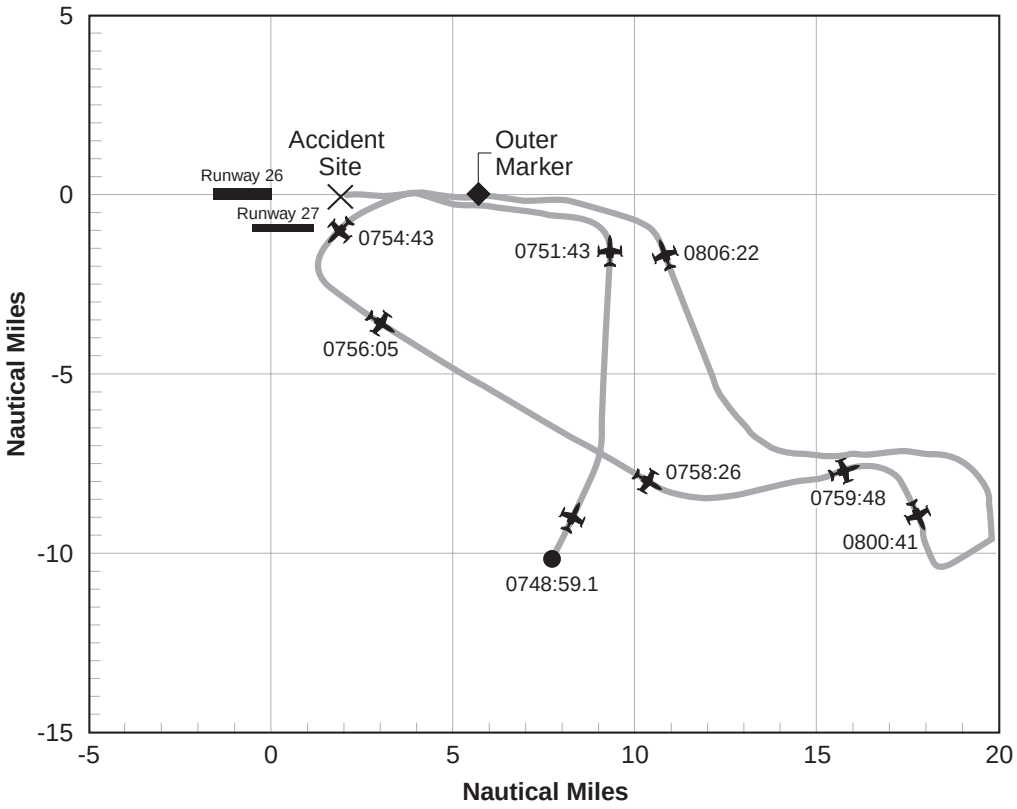
The report said, "Radar data indicated that the airplane began a descent from 2,000 feet [at] about 0753:17 from about 0.5 [nautical mile (0.9 kilometer)] inside NIXIN (the final approach fix) on the left edge of the localizer course. The airplane descended to 1,600 feet, where it intercepted the center of the localizer course approximately 1.5 [nautical miles (2.8 kilometers)] inside NIXIN."

At 0753:47, the captain said, "I got a compass flag." The appearance of the compass warning flag indicated that the heading display on the captain's HSI was not reliable.

The airplane began to fly away from the localizer course. The airplane maintained a ground track of approximately 239 degrees for approximately 50 seconds and descended to 700 feet.

At 0754:43, the tower controller told the crew to report their heading. At this time, the airplane was crossing the extended centerline of Runway 27 and was about 0.8 nautical mile (1.5 kilometers) from the threshold of Runway 27.

Ground Track of Gates Learjet 25B, Houston, Texas, United States, Jan. 13, 1998



Source: U.S. National Transportation Safety Board

Figure 2

Cockpit Voice Recorder Transcript, Gates Learjet 25B, Houston, Texas, U.S., Jan. 13, 1998

(FSF editorial note: The following transcript begins when the flight crew is being vectored to conduct their second instrument landing system [ILS] approach to Runway 26 at George Bush Intercontinental Airport. The transcript is as it appears in the U.S. National Transportation Safety Board accident report, except for minor column rearrangement and addition of notes defining some terms that may be unfamiliar to the reader. Times are local.)

Time	Source	Content
0801:32	**CAM-2**	three thousand … threeee six zero. watch your RMI … I know it's hard Bill but you're gonna do …
0801:42	**CAM-1**	yeah I know, I, I think I got it figured out now.
0801:44	**CAM-2**	all right. RMI three six zero going * *.
0801:46	**CAM-1**	all right, here we go.
0801:52	**RDO-2**	how's that Houston, three six uh, six two seven Whiskey sierra.
0801:55	**APR**	Lear seven Whiskey Sierra looks fine now ma'am. turn left heading of three two zero ah, I tell you what. turn left heading three zero zero. there's areas of weather popping up there on about uh, fifteen to twenty mile final. try to take you south of that and get you inside of 'em.
0802:07	**RDO-2**	three two zero left turn, Whiskey Sierra.
0802:12	**CAM-2**	watch the RMI … I think once we get punched out …
0802:20	**APR**	Lear seven Whiskey Sierra continue the left turn heading two eight zero and I'll have to turn you back to the north when I get you clear of that weather.
0802:24	**CAM-1**	OK, two eight zero.
0802:26	**RDO-2**	two eight zero, Whiskey Sierra.
0802:29	**CAM-1**	I got it figured out now.
0802:31	**CAM-2**	all right. it, you know it's just it's very disorienting.
0802:34	**CAM-1**	yeah, right on the …
0802:36	**CAM-2**	oh #, that * *.
0802:38	**APR**	information Foxtrot is current on the uh, ATIS at Intercontinental now. the wind three five zero at six. the uh, weather is less than a quarter mile visibility light rain and uh, mist. two hundred uh, measured ceiling two hundred broken six hundred overcast. altimeter three zero zero one the runway two six RVR's more than six thousand.

The first officer did not report the airplane's heading; she declared a missed approach. The tower controller told the crew to turn left to a heading of 120 degrees, to climb to 3,000 feet and to contact the approach controller. The first officer told the approach controller that the flight would return to KHOU.

The captain then told the first officer, "No, we just need to fly around. … We got a problem we need to figure out."

The first officer told the approach controller, "Captain says uh, we're gonna fly around if you can put us out uh, we're gonna try to straighten something out."

The approach controller asked if the crew had a problem with the aircraft, and the first officer said, "Just the compass. We're working on it."

"According to CVR data, the captain and first officer spent the next few minutes attempting to clear the compass flag by resetting circuit breakers," the report said. "The CVR recording provides no indication that the problem was resolved."

At 0758:26, the approach controller said, "Turn left heading zero eight zero, and uh, have you got anything worked out yet?"

The first officer said, "Zero eight zero. We're looking at it right now."

At 0759:10, the captain told the first officer, "Well, let's go back to Hobby … we can't do a trip like this." The captain then said, "Well now, let's think about this a second."

The first officer inquired about weather conditions at Fargo. The captain said that the weather conditions at Fargo were "severe clear." The captain then said, "Let's go on and try Intercontinental again. … Tell him we wanna go back and try the approach again."

The first officer requested another approach, and the approach controller told the crew to fly a heading of 350 degrees and to maintain 3,000 feet. The first officer repeated the clearance.

The captain asked the first officer, "Right turn to three five zero?"

The first officer said, "Yeah."

The controller saw that the airplane was in a right turn, toward the south, and, at 0800:41, said, "Hey, Lear seven Whiskey Sierra, the compass is messed up ma'am. You're turning southbound. I need you to turn northbound heading three, six, zero."

The first officer said, "That was a left turn to three six zero … ."

At 0801:55, the approach controller said, "I tell you what. Turn left heading three zero zero. There's areas of weather popping up there on about uh, fifteen to twenty mile final. Try to take you south of that and get you inside of 'em." The report said that air traffic control (ATC) radar depicted scattered areas of

level 1 precipitation, level 2 precipitation and level 3 precipitation east of the airport.

At 0802:20, the controller said, "Continue the left turn heading two eight zero, and I'll have to turn you back to the north when I get you clear of that weather." The controller then told the crew to descend to 2,000 feet.

The first officer told the captain twice (at 0801:32 and at 0802:12) to "watch [your] RMI [radio magnetic indicator]."

At 0802:29, the captain said, "I got it figured out now."

The first officer said, "All right. It, you know, … it's very disorienting."

At 0803:57, the approach controller told the crew to turn right to a heading of 320 degrees. The first officer correctly read back the clearance but then told the captain "two seven zero."

The captain said, "Two eight, what'd what'd he want? Three … ."

The first officer said, "Two eight zero … ."

The captain said, "No, uh, three two zero."

At 0804:44, the approach controller said, "Turn right heading of three four zero, and you should be on the uh, west side of the weather now."

The first officer correctly repeated the instruction, but at 0805:31 told the captain "Heading three two zero." At 0806:08, she said, "OK, three two zero … ."

The captain said, "No, three four zero."

The first officer said, "Oh, you're right, three four zero."

At 0806:22, the approach controller said, "Turn left heading two niner zero. You're five miles from the outer marker. Two thousand till established. Cleared ILS runway two six approach." The airplane's groundspeed at this time was approximately 180 knots (333 kph).

The pilots again did not follow the instrument-approach crew-coordination procedures described in the operator's training manual. The CVR transcript indicates that the required altitude callouts were not made.

"The crewmembers did not discuss how to fly the approach with the unresolved [compass] problem, and neither crewmember conducted an approach briefing," said the report.

At 0807:53, the tower controller cleared the crew to land.

The first officer then told the captain, "OK, you are cleared to land. Apparently, it the glideslope (isn't) working. I can't

0802:56	**CAM-2**	OK.
0802:57	**RDO-2**	sounds good, Whiskey Sierra. thank you.
0803:02	**CAM-2**	all right Bill …
0803:03	**APR**	Lear seven Whiskey Sierra descend and maintain two thousand.
0803:04	**RDO-2**	two thousand, Whiskey Sierra.
0803:06	**CAM**	[sound similar to altitude alert signal]
0803:06	**CAM**	[sound similar to decrease in engine RPM]
0803:09	**CAM-2**	not for the light hearted.
0803:10	**CAM-1**	no.
0803:12	**CAM-2**	all right, I have it on …
0803:13	**CAM**	[sound similar to altitude alert signal]
0803:14	**CAM-2**	… it's on manual and then I when we start getting in there I can put it on automatic. has to be within some limitation. * *.
0803:22	**CAM-1**	* * *. the DME is on what now?
0803:25	**CAM-2**	it's on the uh, localizer.
0803:25	**CAM-1**	OK.
0803:26	**CAM-2**	or on the uh, system.
0803:27	**CAM-1**	OK.
0803:29	**CAM-2**	OK, we are heading, two seven zero. we're going west. so they're gonna bring us back around.
0803:35	**CAM-1**	yeah.
0803:37	**CAM-2**	out of two thousand, seven hundred and seventy for two thousand. is the radio too loud for you Bill?
0803:43	**CAM-1**	no, it's fine.
0803:45	**CAM-2**	OK, oh I see a bank. wow, it's just like a blanket. we're heading west Bill so they're gonna bring us in, it'd be nice if they could bring us around to the north.
0803:54	**CAM-1**	well, it would be nice.
0803:57	**APR**	Lear seven Whiskey Sierra, turn right heading three two zero.
0803:59	**RDO-2**	three two zero, Whiskey Sierra.
0804:12	**CAM-2**	two seven zero.
0804:23	**CAM-1**	two eight, what'd what'd he want? three …
0804:24	**CAM-2**	two eight zero.
0804:25	**CAM-1**	no, uh, three two zero.
0804:26	**CAM-2**	three two zero.
0804:27	**CAM-1**	yeah.

0804:27	**CAM-2**	I got it. I put it on my heading bug.
0804:28	**CAM-1**	yeah. I did too.
0804:29	**CAM-2**	OK three ten?
0804:38	**CAM-2**	three hundred feet to go.
0804:44	**APR**	Lear Seven Whiskey Sierra turn right heading of three four zero and you should be on the uh, west side of the weather now.
0804:50	**RDO-2**	three four zero, Whiskey Sierra.
0805:04	**CAM-2**	OK, two thousand feet, excellent.
0805:08	**CAM**	[sound similar to increase in engine RPM]
0805:13	**CAM-2**	you might bring 'em up even. you want me to do it for you?
0805:15	**CAM-1**	I need to bring it up a little more anyway.
0805:17	**CAM**	[sound similar to increase in engine RPM]
0805:18	**CAM-2**	all right. I'll do it for you.
0805:18	**CAM-1**	get it up to eighty.
0805:19	**CAM-2**	OK.
0805:22	**CAM-1**	hold it, hold it there.
0805:24	**CAM-2**	all right. tell me if you …
0805:25	**CAM-1**	's all right.
0805:26	**CAM-2**	I'll do it for you. I'll do it all for you.
0805:27	**CAM-1**	naw naw, I can do it.
0805:28	**CAM-2**	OK I just wanted to let you know Bill.
0805:29	**CAM-1**	OK.
0805:29	**CAM-2**	I'm here to help.
0805:30	**CAM-1**	I know you are. you're doing a great job.
0805:31	**CAM-2**	I'm not doing anything. two thousand heading three two zero excellent. one hundred eighty knots. cruising.
0806:03	**CAM-1**	how do you synch these V bars?
0806:08	**CAM-2**	there's a pitch … OK, three two zero Bill.
0806:12	**CAM-1**	no, three four zero.
0806:15	**CAM-2**	oh, you're right. three four zero.
0806:16	**CAM-1**	yeah.
0806:17	**CAM-2**	OK, three four zero on my side.
0806:22	**APR**	Lear Seven Whiskey Sierra turn left heading two niner zero. you're five miles from the outer marker. two thousand till established. cleared ILS runway two six approach.

watch it … ." The CVR recorded no further discussion about the first officer's glideslope-indication problem.

Radar data and CVR data indicated that the captain had difficulty tracking the localizer course. The report said that, although the captain's compass problem had not been resolved, the captain's RMI provided accurate heading information.

At 0808:18, the first officer said, "You're left of course … you're at the outer marker." The airplane's groundspeed was approximately 160 knots (296 kph). The first officer said, "Gear's down. You want full … "

The captain said, "Full flaps."

The first officer asked if he wanted to wait, and the captain said, "No, full flaps."

At 0808:34, the airplane was outside the left edge of the localizer course, and the first officer said, "Quit turning. Quit turning. We're gonna go through it. Follow mine right here."

A few seconds later, the first officer said, "Glideslope's engaged. You're above glideslope. … OK, ease your wings back. To the right, to the right, to the right … turn it. Lookin' good."

The captain said, "All right. Can you fly it?"

The first officer said, "Yeah, I think so."

When control of the airplane was transferred from the captain to the first officer, the Learjet was approximately 1.9 nautical miles (3.5 kilometers) inside the outer marker (NIXIN), slightly below the glideslope and on the localizer centerline. Groundspeed was approximately 150 knots (278 kph).

The report said that although the first officer had noticed a problem with her glideslope indicator, both pilots apparently were using her glideslope indicator for reference.

At 0809:08, the captain said, "Where's your glideslope?"

The first officer said, "Right here."

The captain said, "OK, look at it."

At 0809:21, the first officer said, "We are way above glideslope."

The captain said, "Right. Ease it on down." The airplane, however, was 200 feet to 300 feet below the glideslope at this time.

At 0809:30, the first officer said, "Where's the missed approach point?"

The captain said, "Two hundred feet."

At 0809:35, the CVR recorded a sound similar to an altitude-alert signal.

The captain said, "Don't worry about that."

The first officer said, "Sloppy. V ref. We're at ref. … OK, three hundred feet to, to missed. OK, I'm breaking out."

At 0809:50, the captain said, "Don't you look up."

The last recorded radar data at 0809:48 showed that the airplane was 2.2 nautical miles (4.1 kilometers) from the runway threshold at an altitude of approximately 400 feet and approximately 400 feet below the glideslope. Four seconds later, the CVR recorded a sound similar to an altitude-alert signal and a slapping sound. At 0809:55, the CVR recorded the sound of impact.

The airplane was at 180 feet (116 feet below decision height) when it struck the tops of 80-foot (24-meter) trees; the cabin section and cockpit section struck the ground approximately 860 feet (262 meters) from the initial tree strike. A fuel-fed fire erupted upon ground impact. The report said that the accident was not survivable.

"Autopsies conducted by the Harris County, Texas, medical examiner determined that the cause of death for both pilots was blunt-force injuries and extensive thermal body burns," said the report. "The medical examiner's toxicological analysis … indicated that no alcohol or performance-impairing drugs were present at the time of death."

The report said that there were three possible reasons why the compass warning flag appeared in the captain's HSI during the first ILS approach.

"According to technical specifications published by the manufacturer, a compass warning flag would come into view on the [HSI] if one of the following events occurred: (1) a loss of electrical power to system components; (2) a failure of the remote directional gyro; or (3) the function of the compass display servomechanisms becomes unreliable," the report said. "The compass display servomechanisms are controlled by the flight-instrument amplifier with input from the remote directional gyro."

Postaccident examination of the Collins VIR-30A navigation receiver that provided information to the first officer's HSI and ADI revealed a failure of the amplifier that controlled the output of glideslope-deviation information.

"This failure resulted in the glideslope pointers on the first officer's [HSI and ADI] giving a false maximum fly-down indication regardless of the airplane's position relative to the glideslope," said the report. The glideslope warning flags in the first officer's HSI and ADI operated "erratically" during tests using various glideslope channels.

0806:29	**RDO-2**	two nine zero, two thousand, we're cleared for the ILS two six, Whiskey Sierra.
0806:34	**CAM-1**	all right, flaps ten.
0806:36	**CAM-2**	ah, are you within the speed limit? yeah … flaps eight. comin' in. you have flaps eight captain.
0806:41	**CAM-1**	whatever it is.
0806:42	**CAM-2**	OK, careful. two … nine zero captain. and two thousand. I'd go slooow slow …
0806:52	**CAM**	[sound similar to decrease in engine RPM]
0806:52	**CAM-2**	… two nine zero.
0806:53	**CAM-1**	all right, flaps twenty.
0806:54	**CAM-2**	flaps twenty. and indicated.
0806:59	**CAM-1**	I got this thing on …
0807:00	**CAM-2**	heading, what do you want?
0807:01	**CAM-1**	what ever it needs to …
0807:02	**CAM-2**	do you want it on?
0807:03	**CAM-1**	put it on automatic. no
0807:04	**CAM-2**	OK, you're not on it.
0807:06	**CAM-1**	yeah but I will. now I am.
0807:08	**CAM-2**	no, you have to be on the frequency.
0807:09	**CAM-1**	all right. get me on the frequency then.
0807:11	**CAM**	[sound similar to altitude alert signal]
0807:14	**CAM-2**	two thousand, two thousand.
0807:21	**APR**	Lear seven Whiskey Sierra, you should be coming up on the localizer now ma'am. contact the tower, one two five point three five.
0807:26	**RDO-2**	thank you for your help. Whiskey Sierra.
0807:28	**APR**	good day.
0807:31	**CAM-2**	two thousand till established.
0807:32	**CAM**	[sound similar to increase in engine RPM]
0807:33	**CAM-2**	and, I'm gonna put mine on automatic as well.
0807:36	**CAM-1**	all right, should it be on glide slope automatic?
0807:38	**CAM-2**	yeah, it varies. sometimes it won't stick. yours won't stick. OK uh.
0807:45	**RDO-2**	Intercontinental tower, Learjet six two seven Whiskey Sierra is back with you. we are two thousand for ILS, twenty six.

0807:53	**TWRB**	Lear six two seven Whiskey Sierra Houston tower runway two six cleared to land. wind three four zero at five. traffic's on departure roll.
0808:00	**RDO-2**	'K, thank you, Whiskey Sierra.
0808:03	**CAM-2**	OK you are cleared to land. apparently it the glideslope (isn't) working. I can't watch it Bill.
0808:11	**CAM-1**	* *.
0808:12	**CAM-2**	OK.
0808:12	**CAM-1**	all right.
0808:13	**CAM-2**	gear down?
0808:14	**CAM-1**	what's the runway heading? yeah, put the gear down.
0808:15	**CAM-2**	two six …
0808:15	**CAM**	[sound similar to landing gear being extended]
0808:16	**CAM-2**	… runway heading two six.
0808:17	**CAM-1**	all right, this thing didn't capture.
0808:18	**CAM-2**	all right, uh, mine is on. if you wish to have it on. uh, you're you're left of course at you're and you're at the outer marker.
0808:25	**CAM-1**	all right.
0808:26	**CAM-2**	gear's down, you want full wa wa wa.
0808:27	**CAM-1**	full flaps.
0808:28	**CAM-2**	you wanna wait?
0808:29	**CAM-1**	no, full flaps.
0808:34	**CAM-2**	OK, and your thrust reversers are armed. do you see my … OK wait Bill. turn, quit turning, quit turning. we're gonna go through it. follow mine right here.
0808:44	**CAM-1**	* you comin' in?
0808:45	**CAM**	[sound similar to altitude alert signal]
0808:48	**CAM-2**	OK, it's comin' in. OK. look at my uh …
0808:49	**CAM**	[sound similar to altitude alert signal]
0808:50	**CAM-2**	… glide slope engaged.
0808:50	**CAM-1**	mine's comin' in now, mine's comin' in.
0808:52	**CAM-2**	glide slope's engaged. you're above glide slope uh, no, watch your foot. OK, ease your wings back. to the right, to the right, to the right, Bill. turn it. lookin' good.
0809:07	**CAM-1**	all right. can you fly it?
0809:08	**CAM-2**	yeah, I think so.
0809:08	**CAM-1**	where's your glide slope?
0809:10	**CAM-2**	right here.

The airplane's maintenance records showed that, two months before the accident occurred, another flight crew had reported that the first officer's glideslope indicators did not function when the navigation receiver was tuned to 109.9 MHz. The report said that an instrument-repair station misdiagnosed the problem as "sticking pointers" in the HSI and ADI.

"American Corporate Aviation was immediately advised of the problem, but a repair, which was required within 10 days [according to provisions of the Learjet's minimum equipment list], was not accomplished," said the report. "Because the investigation revealed no evidence of any problems with the captain's glideslope receiver, the captain's [HSI and ADI] glideslope pointers were likely giving a proper fly-up indication. However, the flight crewmembers failed to cross-check their glideslope indications, which might have alerted them to the airplane's increasing deviation below the glideslope."

Air traffic controllers did not receive a minimum safe altitude warning (MSAW) before the Learjet struck the terrain.

"Because of its position, heading and status as an KIAH arrival, [the Learjet] was subject to approach-path monitoring at the time of the accident," the report said.

An MSAW normally is generated when the automated radar tracking system (ARTS, an ATC radar-data processing system) determines that an aircraft will descend below a predetermined *alert threshold* within the monitored area.

The approach-path monitored area for KIAH Runway 26 extended from the final approach fix to two nautical miles from the runway threshold, and from one nautical mile left of the extended runway centerline to one nautical mile right of the extended runway centerline. At the time of the accident, the alert threshold for the approach-path monitored area was set to 100 feet above ground level (AGL). After the accident, FAA recalculated MSAW parameters for all KIAH runways and reset the alert threshold for Runway 26 approach-path monitored area to 402 feet AGL.

At NTSB's request, FAA tested the preaccident alert threshold and the postaccident alert threshold against radar data recorded during the Learjet's second ILS approach. An MSAW was not generated during the test of the preaccident alert threshold. An MSAW was generated five seconds before impact during the test of the postaccident alert threshold.

The report said that the accident might have been prevented if the crew had conducted the instrument-approach crew-coordination procedures described in the operator's training manual.

"If the procedure[s] had been followed, the flight crew would have been aware throughout the approach of the airplane's position relative to the published DH [decision height] and might have taken action to arrest the airplane's descent at DH

until visual contact with the runway environment was established," said the report.

The accident also might have been prevented if the airplane had been equipped with a ground-proximity warning system (GPWS).

"According to data supplied by a U.S. manufacturer of GPWS equipment, the flight profile of the accident airplane indicated that, if the airplane had been equipped with a GPWS, a mode-5 [descent-below-glideslope] aural warning would have sounded approximately 40 seconds before initial impact at an altitude of 1,100 feet," said the report. "Two additional aural mode-5 warnings would have sounded about 34 [seconds] and 14 seconds before impact. Further, a mode-1 [excessive-sink-rate] aural warning would have sounded about 11 seconds before impact at an altitude of 600 feet … . The aural mode-1 warning would have continued to the end of the flight.

"With the assumption that the glideslope input to the GPWS was functioning, the warnings would have provided adequate time to allow the flight crew to take appropriate action to avoid impact with the terrain."

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

- "Issue a flight standards information bulletin to principal operations inspectors assigned to [FARs] Part 135 on-demand air carriers, informing them of the circumstances of this accident and urging them to discuss the accident with their air carriers and [to] encourage the use of the accident as a pilot-training case study, to stress the importance of pilots' adherence to standard operating procedures," and,

- "Require, within three years, that all turbine-powered airplanes with six or more passenger seats that are not currently required to be equipped with a [GPWS] have an operating enhanced GPWS [EGPWS] (or terrain awareness and warning system [TAWS])."

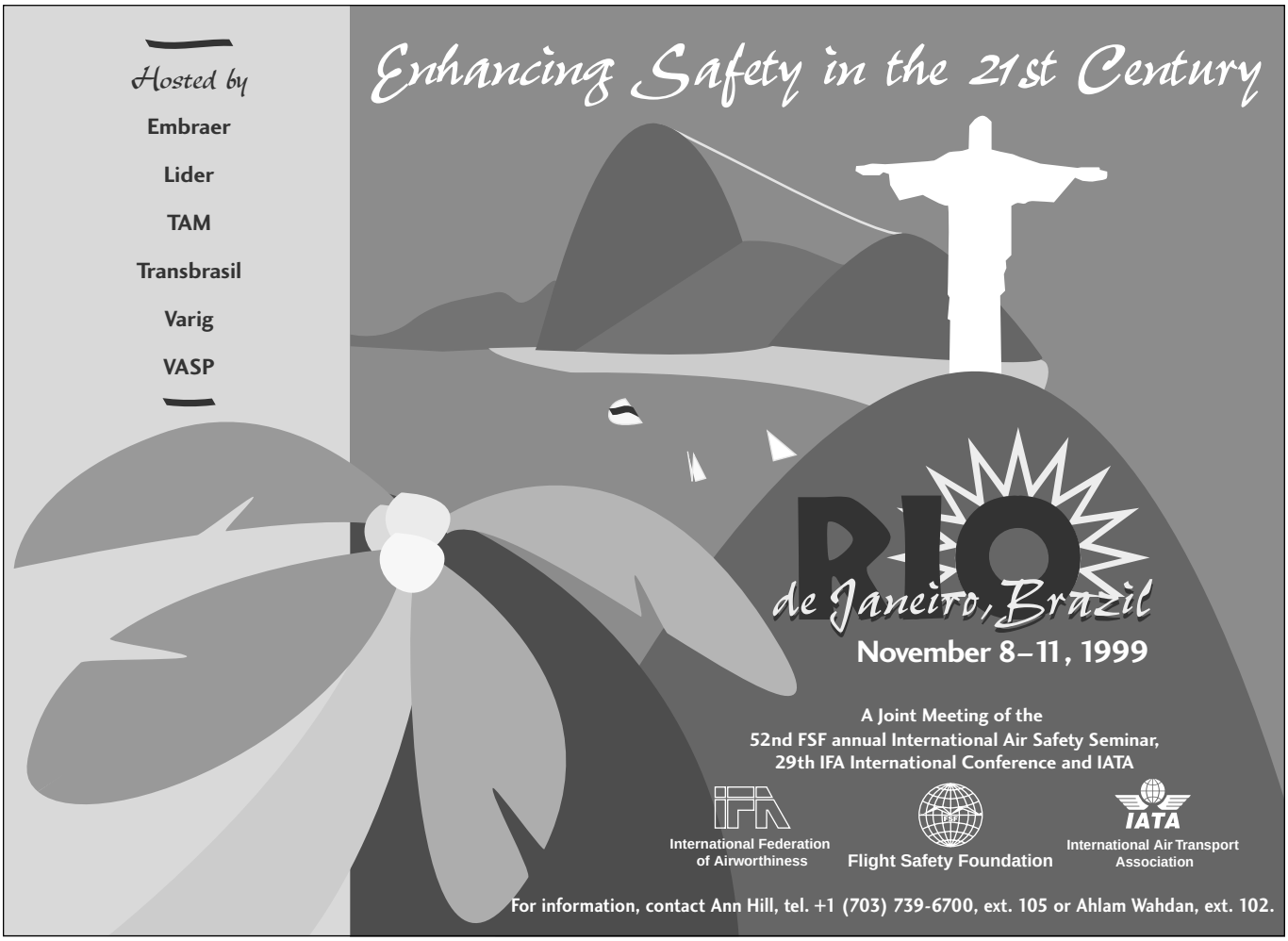
[Editorial note: When NTSB published this accident report, the FAA was soliciting public comments on a notice of proposed rule making that would require TAWS equipment to be installed on turbine-powered airplanes with six or more passenger seats within four years of a final rule's effective date. TAWS includes EGPWS, a system developed by AlliedSignal, and other manufacturers' systems that provide terrain warnings that could prevent controlled-flight-into-terrain (CFIT) accidents.]♦

[Editorial note: This article, except where specifically noted, is based entirely on U.S. National Transportation Safety Board (NTSB) Factual Report FTW98MA096, NTSB Brief of Accident FTW98MA096 and NTSB Safety Recommendation A-99-35 and -36. The 700-page factual report contains diagrams and appendixes.]

0809:10	**CAM-1**	OK.
0809:11	**CAM-1**	look at it.
0809:12	**CAM-2**	I got it.
0809:13	**CAM-2**	all right, watch my uh, watch the uh, missed approach for a … watch the speed.
0809:19	**CAM-1**	roger, descending too much.
0809:21	**CAM-2**	am I, yeah, yeah. keep, we are way above glide slope.
0809:24	**CAM-1**	right. ease it on down. * * * *.
0809:27	**CAM-2**	OK.
0809:28	**CAM-1**	don't look out.
0809:30	**CAM-2**	all right, where's the missed approach point Bill.
0809:32	**CAM-1**	two hundred feet.
0809:35	**CAM**	[sound similar to altitude alert signal]
0809:36	**CAM-1**	don't worry about that.
0809:39	**CAM-2**	sloppy. V ref. we're at ref.
0809:45	**CAM-2**	OK. three hundred feet to, to missed. OK, I'm breaking out.
0809:50	**CAM-1**	don't don't you look up.
0809:51	**CAM-2**	OK.
0809:54	**CAM**	[sound similar to altitude alert signal]
0809:54	**CAM**	[slapping sound]
0809:54	**CAM-2**	oh, oh, #.
0809:55	**CAM**	[sound of impact]
0809:56	**CAM-2**	oh # #.
0809:56		**End of Recording**

RDO = Radio transmission from accident aircraft
CAM = Cockpit area microphone voice or sound source
APR = Radio transmission from Houston approach controller
TWRB = Radio transmission from the George Bush Intercontinental Airport tower controller
-1 = Voice identified as pilot-in-command
-2 = Voice identified as copilot
* = Unintelligible word
\# = Expletive
( ) = Questionable insertion
[ ] = Editorial insertion
… = Pause
ATIS = Automatic terminal information service
DME = Distance-measuring equipment
RMI = Radio magnetic indicator
RPM = Revolutions per minute
RVR = Runway visual range

Source: U.S. National Transportation Safety Board



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