

THE "CALI" ACCIDENT

Original idea from the Flight Safety Foundation

The crew of a Boeing 757-223, Flight 965, was transitioning from cruise flight to a very high frequency omni-directional radio range (VOR) / distance measuring equipment (DME) instrument approach to runway 19 at the Alfonso Bonilla Aragon International Airport (SKCL), Cali, Colombia, when the aircraft collided with a mountain 53 kilometers (33 miles) northeast of the CALI VOR.

The two flight crew members, six cabin crew members and 151 passengers were killed. Five passengers survived the December 20, 1995, accident, but one of them later died as a result of injuries sustained in the accident. The aircraft was destroyed.

The accident occurred at night in visual meteorological conditions (VMC).

The official report of the Aeronautica Civil of the Republic of Colombia said that "the probable causes of this accident were:

- (1) The flight crew's failure to adequately plan and execute the approach to runway 19 at SKCL, and their inadequate use of automation.
- (2) Failure of the flight crew to discontinue the approach into Cali, despite numerous cues alerting them of the inadvisability of continuing the approach.
- (3) The lack of situational awareness of the flight crew regarding vertical navigation, proximity to terrain and the relative location of critical radio aids.
- (4) Failure of the flight crew to revert to basic radio navigation at the time when the FMS assisted navigation became confusing and was demanding an excessive workload in a critical phase of the flight".

The report also said that "contributing to the cause of the accident were:

- (1) The flight crew's on-going efforts to expedite their approach and landing in order to avoid potential delays.
- (2) The flight crew's execution of the GPWS escape manoeuvre while the speedbrakes remained deployed.
- (3) FMS logic that dropped all intermediate fixes from the display(s) in the event of execution of a direct routing.
- (4) FMS generated navigational information that used a different naming convention from that published in navigational charts".

Flight 965's route "was from MIA through Cuban airspace, then through Jamaican airspace and into Colombian airspace, where the flight was re-cleared by Barranquilla Air Traffic Control Centre (Barranquilla Centre) to proceed from KILER intersection direct to BUTAL intersection", the report said. "The flight then passed abeam Cartagena [VOR] (CTG). Bogota Centre subsequently cleared the flight to fly direct from BUTAL to the TULUA VOR [ULQ]."



When the flight passed BUTAL intersection, Bogota Centre again cleared the flight from its present position to ULQ, and told the flight to report when they were ready to descend, the report said. At 2110, the crew obtained the Cali weather from the system operations control centre via the onboard aircraft communications addressing and reporting system (ACARS).

The crew was given the following weather observation for Cali, reported at 2000 hours local time: scattered clouds at 1700 feet and 10,000 feet, visibility more than six miles, surface wind from 160 degrees at four knots, temperature 23 degrees C and dew point 18 degrees C.

En route, the flight crew discussed the crew rest requirements for the cabin crew members. Because of the flight's delayed departure from MIA, the captain was concerned that the cabin attendants would not have the U.S. Federal Aviation Administration (FAA)-required rest period before the crew's scheduled departure time the following morning.

As they prepared to descend from cruise, the captain told the first officer, who was the pilot flying, " ... If you'd keep the speed up in the descent ... it would help us too, okay?"

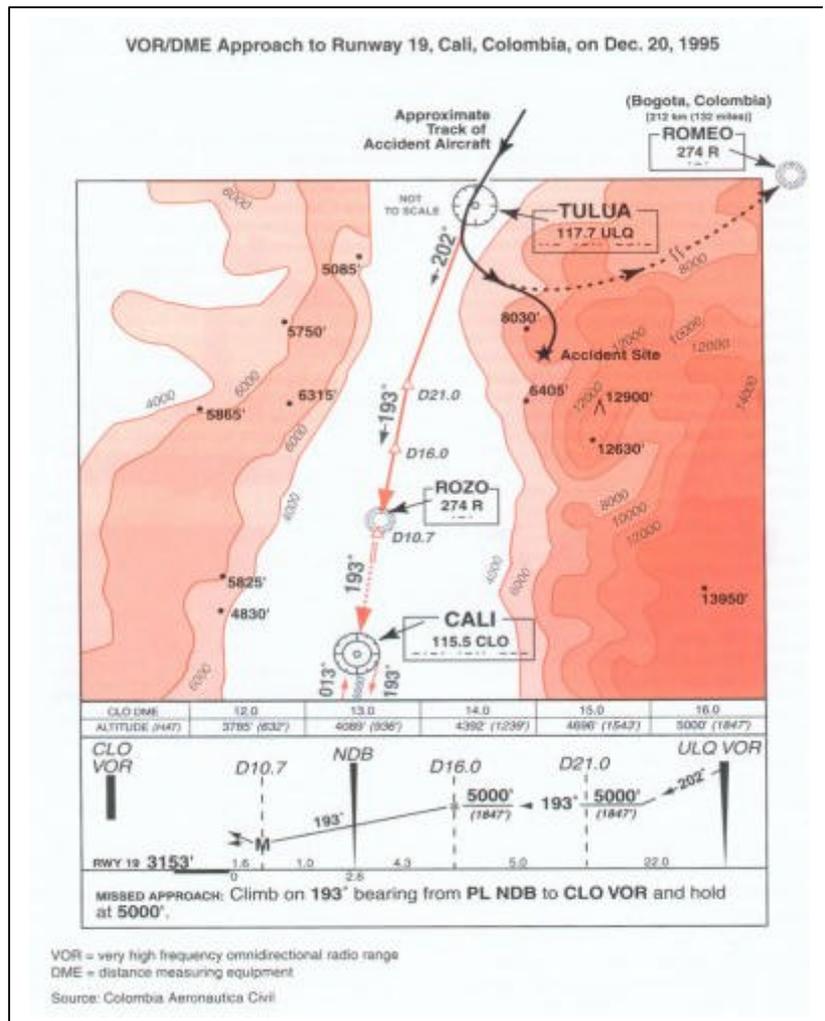
At 2126:20, Bogota Centre cleared the flight to descend from its cruising altitude of FL370 down to FL 240.

At 2131:53, the crew reported to Bogota Centre that the aircraft was level at FL 240 and the controller told the crew to expect a lower altitude in two minutes.

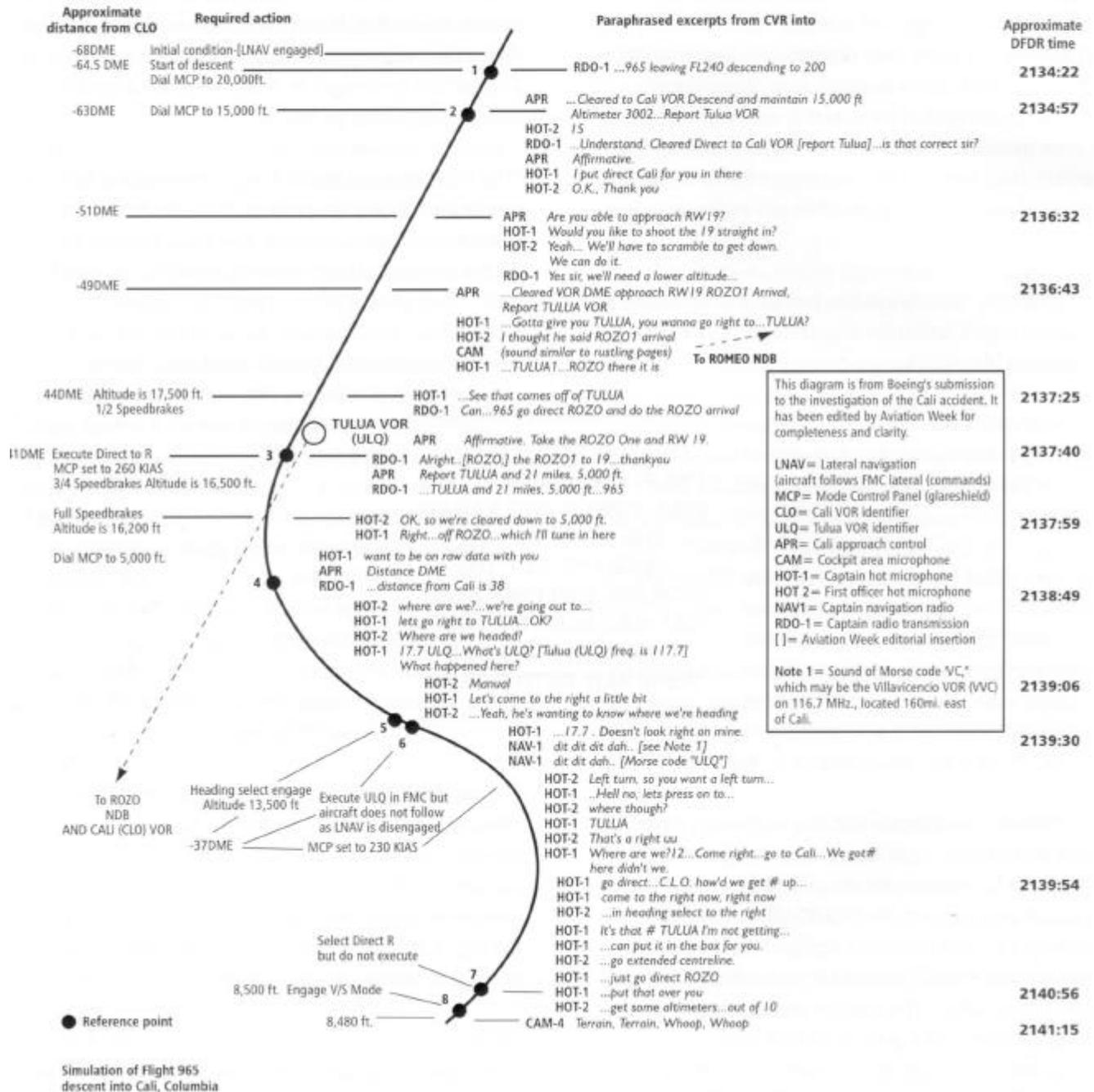
About two minutes later, the first officer said to the captain, "Well, if she [the Bogota Centre controller] doesn't let us down in a little while, she's goin' to put me in a jam here". The captain then called Bogota Centre and requested a lower altitude. The flight was cleared down to FL200. "At 2134:04, the flight was instructed to contact Cali Approach Control," the report said. When the captain contacted Cali Approach, the controller requested the flight's DME distance from the CALI VOR. The captain replied that they were 63 DME from CALI VOR.

The controller then cleared the flight to the CALI VOR, to descend to 15,000 feet, and to report the TULUA VOR. When the captain read back the clearance, he said, "Okay, understood. Cleared direct to CALI VOR. Uh, report TULUA and altitude one five, that's fifteen thousand Is all that correct, sir?" The controller replied, "Affirmative."

The captain then told the first officer he had entered a direct route to the CALI VOR in the FMS. At 2136:31, Cali Approach asked the crew if they were able to approach and land on runway 19. After a brief discussion with the first officer, the captain replied that they would accept the approach to runway 19, but would need a lower altitude immediately. The controller then cleared the flight for the VOR/ DME instrument approach to runway 19, the ROZO One Arrival, and again instructed the crew to report the TULUA VOR.



The B757 Flight Path Crew Actions/CVR



The captain acknowledged the clearance and said, "Will report the VOR" The controller once again instructed the crew to report the TULLUA VOR, which the captain acknowledged.

The flight crew discussed which fix they should navigate to next. The captain said, "I gotta give you to TULLUA first of all. You, you wanna go right to CAL, or to TULLUA?"

The first officer said, *"Uh, I thought he said the ROZO One arrival?"*

The captain said, *"Yeah he did. We have time to pull that out(?)"*

After the sound of rustling pages was heard on the cockpit voice recorder (CVR), the captain said, *"ROZO ... there it is."*

After the discussion, the captain asked Cali Approach if the flight could proceed direct to the ROZO non-directional beacon (NDB) and execute the ROZO One arrival. The controller replied, *"Affirmative, take the ROZO" One* After the captain acknowledged, the controller told him to report TULUA and the 21 DME fix at 5000 feet.

(The aircraft's flight data recorder showed that the flight passed TULUA during this exchange and *"began to turn left of the cleared course and flew on an easterly heading [of 100 degrees] for approximately one minute,"* the report said. "Then the aircraft turned to the right. while still in the descent.")

At 2138:39, Cali Approach asked the flight for a position report, which the captain reported as 38 DME from the CALI VOR.

Immediately following the exchange with Cali Approach, the first officer asked the captain, *"Uh, where are we..."*

At one point, the crew apparently realized they had passed TULUA and the first officer asked, *"... So you want a left turn back around to ULQ?"* The captain responded that they should *"press on"*, and told the first officer to *"come to the right"* and proceed to the CALI VOR.

At 2140:01, the captain told Cali Approach that they were *"thirty-eight [nautical] miles"* north of CALI VOR, and asked if they should proceed to TULUA and execute the ROZO One arrival to runway 19. The controller replied that they could use runway 19, and asked for their altitude and DME from CALI. The captain reported they were 37 DME from CALI, and at 10,000 feet.

The cockpit conversation suggested that the crew was still experiencing difficulty getting orientated to the TULUA VOR on the FMS display. The first officer finally said, *"I don't want TULUA. Let's just go to the [runway 19] extended centreline"*

At 2141:02, Cali Approach asked the crew to report their altitude, which the captain reported as 9000 feet. The controller then asked for their distance from CALI. Before the captain could respond, the aircraft's GPWS sounded, *"Terrain, terrain, whoop, whoop"*.

Shortly thereafter, the sound of the autopilot disconnect warning could be heard on the CVR. The GPWS continued to alarm, and the aircraft stick shaker could be heard.

"The FDR showed that the flight crew added full power and raised the nose of the aircraft, but the spoilers (speedbrakes) that had been extended during the descent were not retracted," the report said. *"The aircraft entered into the regime of stick-shaker stall warning, nose-up attitude was lowered slightly, the aircraft came out of stick then increased and stick shaker was re-entered."*

The aircraft struck trees on the east side of a mountain at an altitude of 8900 feet. It then "continued over a ridge near the summit and impacted and burned on the west side of the mountain ... " the report said. *"The elevation of the top of the ridge was about 9000 feet."*

The report described the accident scene: *"The initial impact area was marked by an area of broken trees, followed by a swath where the trees had been essentially flattened or uprooted. The area of uprooted trees began about 250 feet below the top of the ridge. The initial impact swath was orientated along a heading of about 220 degrees."*

Wreckage that was found at the beginning of the wreckage path included thrust-reverser parts, a fan cowling, an APU tail cone, flap jackscrews, an engine fire bottle, the FDR and a small section of wing. The pattern of broken trees indicated that the aircraft initially struck at a high nose-up attitude.

"The main wreckage came to rest on the west side of the ridge, about 400 feet to 500 feet from the top. In addition to the engines, the largest portion of wreckage included the cockpit, a section of centre fuselage about 35 feet long, the CVR, aviation electronics (avionics) boxes, a section of the aft fuselage and a portion of the wing centre section...."

"There was limited post-impact fire, where the main fuselage came to rest"

Investigators determined that the aircraft's FMS had been programmed for the instrument landing system (ILS) approach to runway 01 at Cali. As a result, investigators believed, the flight crew had initially expected to navigate to the CALI VOR (located 8.6 miles south of runway 01), execute the published course reversal at the VOR and proceed inbound on the ILS to runway 01.

The report said: *"The evidence of the hurried nature of the tasks performed and the inadequate review of critical information between the time of the flight crew's acceptance of the offer to land on runway 19 and the flight's crossing the initial approach fix, ULQ, indicates that insufficient time was available to fully or effectively carry out these actions. Consequently, several necessary steps were performed improperly or not at all and the flight crew failed to recognize that the aircraft was heading towards terrain, until just before impact. Therefore, Aeronautica Civil believes that flight crew actions caused this accident."*

In reviewing the flight crew's lack of situational awareness regarding the nav aids and terrain during their descent, investigators also found that "the flight crew's situation[a] awareness was further compromised by a lack of information regarding the rules which governed the logic and priorities of the navigation database in the FMS," the report said.

For example, *"the captain established the flight path that initially led to the deficiency in situation[a] awareness by misinterpreting the Cali"*

Approach controller's clearance to proceed to CALI, given at 2134:59, as a clearance 'direct to' CALI," the report said. The captain's readback of "cleared direct to CALI VOR, report Tulua" received an affirmative response from the controller.

"The captain's readback was technically correct because he stated that he was to report TULUA, thus requiring him to report 'crossing' the fix first," the report said. "However, the CVR indicates that the captain then executed a change in the FMS-programmed flight path to proceed 'direct to' the CALI VOR. In so doing, he removed all fixes between the airplane's present position and CALI, including TULUA, the fix they were to proceed towards."

Investigators found no evidence *"that either pilot recognized that ULQ had been deleted from the display until they were considerably closer to CALI, and were in fact past ULQ at that time,"* the report said. *"Consequently, largely as a result of this action, the flight crew crossed the initial approach fix, ULQ, without realizing that they had done so and without acknowledging the crossing to the controller."*

The report said: *"The logic of the FMS that removed all fixes between the airplane's present position and the 'direct to' fix compromised the situational awareness of the flight crew Since the initial certification of the FMS on the B-757/767, the Boeing Co. has developed and implemented a change to the B-757 software that allowed such fixes to be retained in the display. However, this retrofit, part of a product improvement package for the airplane, had not been incorporated into the accident airplane."*

The accident flight crew was "experienced in the airplane, and was described as proficient in the use of the FMS by their peers," the report said. *"Yet, most likely because of the self-induced time pressure and continued attempts to execute the approach without adequate preparation, the flight crew committed a critical error by executing a change of course through the FMS without verifying its effect on the flight path."*

Investigators found evidence that *"either the captain or the first officer selected and executed a direct course to the identifier 'R,' in the mistaken belief that R was ROZO as it was identified on the approach chart,"* the report said.

In the wreckage of the accident airplane, investigators recovered circuit cards from the airplane's FMS that contained nonvolatile memory. These components, along with portions of the airplane's FMS and flight management computer (FMC), were shipped to Honeywell Air Transport Systems (the equipment manufacturer) for examination.

When power was applied to the FMC and its memory was restored, the FMC-planned route for the accident flight was displayed. The navigational fixes displayed showed the flight proceeding from ULQ to CLO, then via the ILS to Runway 01. The FMC also displayed a modification to the stored route.

Tests were then conducted using a B-757 fixed-base simulator and an FMS bench-type simulator.

The study found that *"calling up 'R' on the CDU displayed a series of waypoints and their coordinates. They were located north and south of the equator, and ordered from top to bottom of the display by their distance from the airplane. 'ROMEO,' a non-directional ... beacon in the city of Bogota, was the first and closest waypoint displayed. 'ROZO,' which was also an NDB, was not displayed, and entering 'R' would not call up Rozo. Rozo could only be called up by spelling out ROZO on the CDU."*

The report said: *"The simulations found that when R was entered into the CDU, a white dashed line pointed off the map display towards the east-northeast. When R was 'executed,' the airplane turned towards R (in the city of Bogota), and the white dashed line turned to a solid magenta colored line on the display."*

As a result, the crew could not have known *"without verification with the EHSI [electronic horizontal situation indicator] display or considerable calculation that instead of selecting Rozo, they had selected the ROMEO beacon, located near Bogota, some 132 miles east-northeast of CALI,"* the report said. *"Both beacons had the same radio frequency, 274 kilohertz, and had the same identifier 'R' provided in Morse code on that frequency."*

"In executing a turn toward ROMEO rather than ROZO, the flight crew had the airplane turn away from CALI and towards mountainous terrain to the east of the approach course, while the descent continued. At this time, both pilots also attempted to determine the airplane's position in relation to ULQ, the initial approach fix."

The report said: *"Neither flight crew member was able to determine why the navaid was not where they believed it should be, and neither noted or commented on the continued descent. The CVR indicates that the flight crew became confused and attempted to determine their position through the FMS."*

Investigators found that *"because of rules governing the structure of the FMS database, ROZO, despite its prominent display as 'R' on the approach chart, was not available for selection as 'R' from the FMS, but only by its full name," the report said. "The evidence indicates that this information was not known by the flight crew of Flight 965."*

The report said: *"The failure to verify and to obtain verbal approval for the execution of the course to 'R' occurred primarily because of the self-induced pressure of the pilots of Flight 965 to execute the approach without adequate time being available."*

"This accident demonstrates that merely informing crews of the hazards of over-reliance on automation and advising them to turn off the automation is insufficient and may not affect pilot procedures when it is needed most," the report said.

Investigators reviewed the use of crew resource management (CRM) by the accident flight crew. The report said that even though the company conducted superior CRM training, the CRM of the accident crew was deficient as neither pilot was able to recognize the following:

- The use of the FMS was confusing and did not clarify the situation.
- Neither pilot understood the steps necessary to execute the approach, even while trying to execute it.
- Numerous cues were available that illustrated that the initial decision to accept Runway 19 was ill-advised and should be change.
- They were encountering numerous parallels with an accident scenario they had reviewed in recent CRM training.
- The flight path was not monitored for over a minute just before the accident.

The report said, *"Although the accident flight crew articulated misgivings several times during the approach, neither pilot displayed the objectivity necessary to recognize that they had lost situational awareness and effective CRM."*

The controller said that *"he restated the clearance and requested [the accident flight's] position relative to the CALI VOR," the report said. "He believed that the pilot's response, that Flight 965 was 37 nautical miles from CALI, suggested that perhaps the pilot had forgotten to report passing the TULUA VOR. The controller further stated that had the pilots been Spanish speaking, he would have told them that their request made little sense, and that it was illogical and incongruent. He said that because of limitations in his command of English he was unable to convey these thoughts to the crew."*

During the investigation, a study was conducted of the performance of Flight 965 following the GPWS warning. The study indicated that *"if the flight crew had retracted the speedbrakes one second after initiating the escape maneuver, the airplane could have been climbing through a position that was 150 feet above the initial impact point," the report said. "... Because the airplane would have continued to climb and had the potential to increase its rate of climb, it may well have cleared the trees at the top of the ridge."*

The report said that *"if the speedbrakes had been retracted upon initiation of the escape maneuver and if the pitch attitude had been varied to perfectly maintain the stick-shaker activation angle, the airplane could have been climbing through a position that was 300 feet above the initial impact point."*

The B-757 incorporates an automatic speedbrakes feature that when activated with the airplane on the ground stows any extended spoiler panels when either thrust lever is advanced from flight idle.

"However, advancing the thrust levers in flight has no effect on deployed speedbrakes," the report said.

Investigators reviewed other large jet transport aircraft and found 37 aircraft types that "do not have an automatic speedbrakes-stowing feature when full forward thrust is used, while at least eight jet airplanes, including one corporate jet, the Airbus A330, A340, Fokker F-28 and F-100 airplanes have such a feature," the report said.

The report noted that "the fly-by-wire airplanes have enhancements to the pitch-control system to compensate for the automatic retraction of the speedbrakes. In addition, Boeing engineers state that, for the B-757, automatic retraction of the speedbrakes in a go-around maneuver may result in unwanted pitch excursions."