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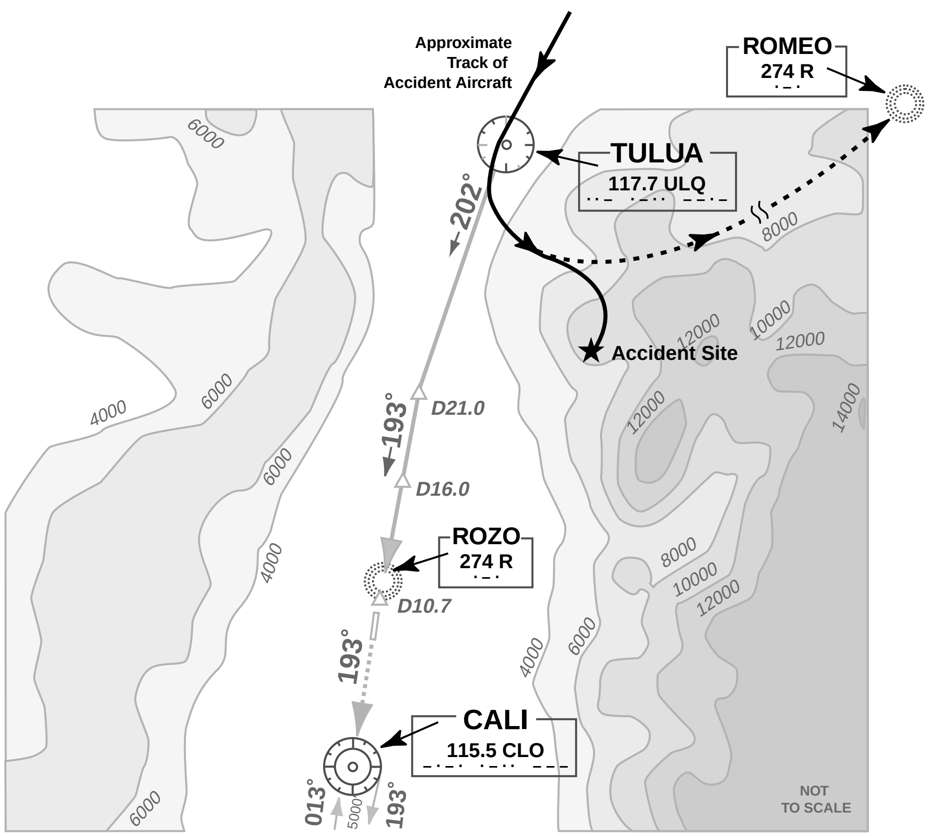
Boeing 757 CFIT Accident at Cali, Colombia, Becomes Focus of Lessons Learned



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In This Issue

Flight Safety Foundation (FSF) is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, FSF was launched in 1945 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 680 member organizations in 77 countries.

Boeing 757 CFIT Accident at Cali, Colombia, Becomes Focus of Lessons Learned

The author has identified 27 errors that he believes were involved in the controlled-flight-into-terrain accident. His analysis suggests specific operational methods and training strategies that might prevent similar accidents.

David A. Simmon

At 2142 local time on Dec. 20, 1995, American Airlines (AA) Flight 965, a Boeing 757-223 on a regular, scheduled passenger flight from Miami, Florida, U.S., to Cali, Colombia, struck mountainous terrain during a descent from cruise altitude in visual meteorological conditions under instrument flight rules. The accident site was near the town of Buga, 33 nautical miles (61 kilometers) northeast of the Cali very high frequency omnidirectional radio range (VOR). The aircraft struck near the summit of El Deluvio, at the 8,900-foot (2,670-meter) level, approximately 10 nautical miles (19 kilometers) east of Airway W3. Of the 163 passengers and crew on board, four passengers survived the accident.

In its final report on the accident, the Aeronáutica Civil of the Republic of Colombia (Aeronáutica Civil) said that the probable causes of the accident were:

- "The flight crew's failure to adequately plan and execute the approach to Runway 19 at SKCL [Cali's Alfonso Bonilla Aragon International Airport], and their inadequate use of automation;

- "Failure of the flight crew to discontinue the approach into Cali, despite numerous cues alerting them of the inadvisability of continuing the approach;

- "The lack of situational awareness of the flight crew regarding vertical navigation, proximity to terrain and the relative location of critical radio aids; [and,]

- "Failure of the flight crew to revert to basic radio navigation at the time when the FMS [flight management system]-assisted navigation became confusing and demanded an excessive workload in a critical phase of the flight."[1]

The Aeronáutica Civil said that factors contributing to the accident were:

- "The flight crew's ongoing efforts to expedite their approach and landing in order to avoid potential delays;

- "The flight crew's execution of the GPWS [ground-proximity warning system] escape maneuver while the speed brakes remained deployed;

- "FMS logic that dropped all intermediate fixes from the display(s) in the event of execution of a direct routing; [and,]

- "FMS-generated navigational information that used a different naming convention from that published in navigational charts."

Representatives from AA, the Allied Pilots Association (APA, the union that represents AA flight crews) and the Boeing Commercial Airplane Group were parties to the accident investigation. The article on page 19 summarizes the party submissions that were made to the Aeronáutica Civil and the U.S. National Transportation Safety Board (NTSB) regarding the investigation, insofar as they added to or differed from the Aeronáutica Civil report.

This analysis of human errors that *might have* contributed to this accident is based upon the aircraft-accident report of the Aeronáutica Civil and the NTSB factual reports from the chairmen of the Operations, Air Traffic Control (ATC), Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) groups. (The NTSB assisted Colombian authorities in the accident investigation.) Explanation of the asterisk and single-letter codes, and definitions of italicized human factors terms that may not be familiar are in "Taxonomy of Human Error," page 3. The analysis uses excerpts from the CVR transcript. The complete CVR transcript is in "Cockpit Voice Recorder Transcript, American Airlines Flight 965, Dec. 20, 1995," page 20.

1. **The crew read back the wrong transponder code.** (*), L, (approximately 2104)

Shortly after contacting Bogota (Colombia) Control, AA 965 was issued the following instruction: "report ready for descent and please squawk code alpha two three one four."

The captain (the pilot not flying [PNF]) said, "OK squawk two two one four uh and report ready for descent, gracias."

This minor error had no bearing on the accident because the controller amended the transponder code to coincide with the code acknowledged by the captain. This error is included because human factors analysis must focus on the error irrespective of the consequences of the error.

2. **The Bogota controller did not advise the Cali controller that AA 965 was proceeding on a direct route to the Tulua VOR.** (**), L, (2104:57–2105:50)

At 2104:57, the controller at Cali Approach Control received a telephone call from the controller at Bogota Area Control Center. The Bogota controller informed Cali Approach of the estimated arrival times and cleared altitudes of the next three aircraft (including AA 965) that were inbound to Cali. The Bogota controller did not, however, advise the Cali controller that AA 965 was proceeding on a direct route to the Tulua VOR. This omission contributed to the subsequent misunderstanding of the "cleared to Cali VOR" clearance.

3. **An adequate approach review was not performed.** (***), K, (2112–2126)

Data indicate that an adequate approach review was not accomplished by the flight crew. There was no information on the CVR either of an approach briefing or that the descent checklist was performed. There was confusion about the aircraft's position and an absence of dialogue about planned speeds, crossing altitudes, radio tuning and management of displays. During this period, the captain was confused about the meaning of ULQ, the Tulua VOR identifier. The CVR transcript showed that there was concern about whether there was time to retrieve the approach chart and that there was a sound similar to rustling pages. The captain took 37 seconds to decide how to implement the amended clearance to Runway 19, and he then requested clearance to Rozo (a nondirectional beacon radio navigation aid [NDB]).

While one of the crewmembers did enter a preliminary arrival path to Runway 01 in the FMS during the flight, this action did not constitute an adequate approach review.

Most crewmembers review the approach prior to the top of descent. This is a low-workload period that allows each crewmember to assess the risks and problems associated with the approach, determine the key physical features of the approach area, derive appropriate operational constraints and calculate the planned landing fuel and the minimum fuel that will be needed if a diversion to the alternate is necessary. This process — *vigilance tuning* — will result in an appropriate focus of attention for each approach.

The approach review should have considered that the approach (a) would be made at night, (b) at a terrain-critical airport, (c) with a nonprecision approach (as well as a precision approach), (d) without the benefit of radar and (e) in a country where the controller's native language (Spanish) was different from the crew's (English). These five conditions are the common elements of most controlled-flight-into-terrain (CFIT) accidents.[2] Moreover, during this review, the crew should have determined the overall approach strategy, management of the radios and displays, and delegation of tasks to manage workload and attention.

The approach review prepares pilots for the approach, arms them for problem solving, allows time for thought during the approach and helps prevent distractions from the primary responsibility to control the flight path.

Completing the approach review and briefing prior to top of descent and then flying the approach as briefed are ideal but not always possible because of operational changes in runways, winds, traffic and other factors. Pilots can accommodate changes, however, as long as they have constructed a general mental picture of the physical features of the approach area, the basic approach geometry and its physical and operational constraints. This *mental model* is

Taxonomy of Human Error

In the accompanying analysis of human error in the accident at Cali, Colombia, errors that are of major concern and are believed likely to have been a link in the chain of events leading to the accident are marked by three asterisks (***); those that are of lesser concern but may have contributed to the accident are marked by two asterisks (**); and those that are minor are marked by a single asterisk (*).

After the asterisk is a single-letter code for the most likely classification of each error using the taxonomy of James Reason, professor of psychology at the University of Manchester (England): lapse = L; slip = S; rule-based mistake = R; and knowledge-based mistake = K.[1] (Five minor radio or read-back errors that are unlikely to have contributed to the accident have been omitted.) Local times are indicated in parentheses.

The analysis is arranged in chronological order. Discussion of the accident from a broader perspective follows the analysis. Human-factors concepts that might be unfamiliar to readers are italicized. Operational definitions of the concepts are provided below in alphabetical order. The operational definitions were derived from James Reason's works and other sources.

Automatic behavior — A rote action performed without awareness or intent. Although automatic behavior allows a person to accomplish a task while thinking about something else, automatic behavior can lead to inattention and error. When a skill is highly learned — perhaps because it has been practiced for years — the skill becomes automated and requires minimal conscious awareness and minimal application of mental effort.

Availability heuristic — A problem-solving mechanism in which an individual is influenced by, and bases decisions on, not only what he or she has experienced in the past but also the situations that most readily come to mind.

Concept shift — A situation in which one or more parameters of a problem change, requiring a person to find a new solution. This condition can cause confusion and delay appropriate decision making if the person is not aware of the parameter change.

Confirmation bias — The expectation of perceiving certain environmental cues, and the tendency to search for those cues more actively than for other cues. The confirmation bias can cause a person to search selectively for evidence to confirm an underlying belief, discount contradictory evidence and stop searching once the confirming evidence is found.

Knowledge-based mistake — An error of commission in which the action proceeds as planned but the plan is inappropriate for the situation. A knowledge-based mistake arises from incomplete or incorrect knowledge.

Lapse — An error of omission in which an item previously known is forgotten. Lapses are unintended and often are caused by inattention or inadequate association at the time the item was learned.

Mental model — An individual's understanding of the elements of a system, operation or situation and the rules of interaction between them.

Metacognitive — A higher type of thinking; thinking about thinking. Metacognition refers to the monitoring and control of one's own thought processes and habit patterns.

Recency bias — The tendency of a person encountering a new situation or event to be influenced by, and to base decisions on, similar information from other situations or events recently encountered.

Rule-based mistake — An error of commission in accordance with a rule that is inappropriate for the situation. A rule-based mistake typically occurs when misclassification of a situation leads to application of an inappropriate rule or to incorrect memory of procedures.

Slip — An error of commission in which the action does not proceed as planned. Slips are unintended and often are caused by inattention at the time of action.

Team building — Bonding individual crewmembers into a team in which each crewmember contributes and facilitates teamwork.

Team participation — Efforts by each crewmember to work with other crewmembers during the flight.

Thought pattern — Expectations that predispose a person to a certain course of action and/or thought, regardless of perceived cues. Attitude and mind-set are related terms that often are used synonymously.

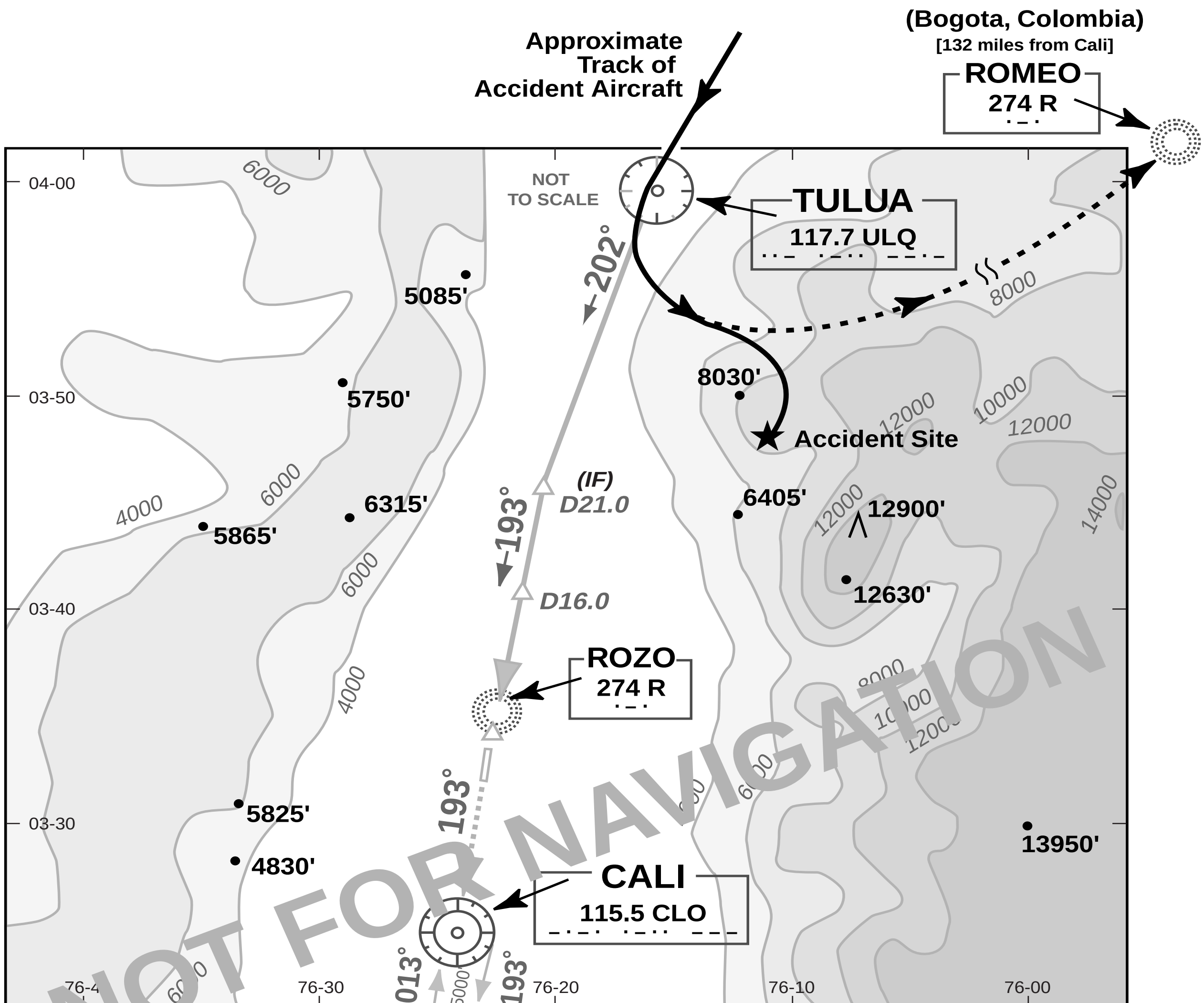
Vigilance tuning — Identifying the important items in a situation that require increased attention and monitoring.♦

— *David A. Simmon*

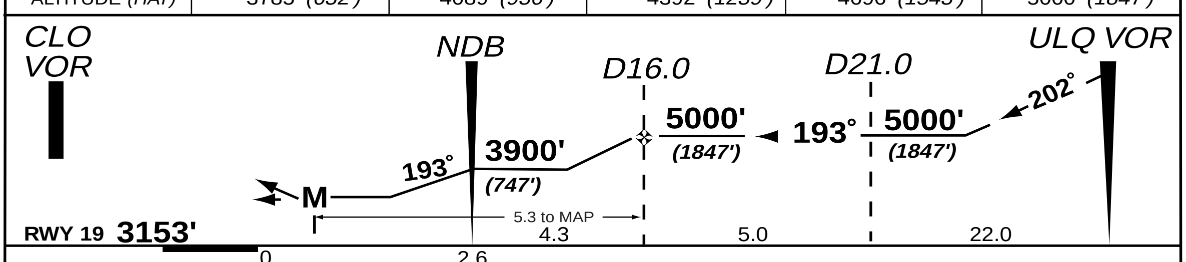
References

1. Reason, James. *Human Error*. Cambridge, England: Cambridge University Press, 1990.

Approximate Track of Flight 965, Cali, Colombia, on Dec. 20, 1995



CLO DME	12.0	13.0	14.0	15.0	16.0
ALTITUDE *(HAT)*	3785' *(632')*	4089' *(936')*	4392' *(1239')*	4696' *(1543')*	5000' *(1847')*



MISSED APPROACH: Climb on **193°** bearing from **R NDB** to **CLO VOR** and hold at **5000'**.

VOR = very high frequency omnidirectional radio range DME = distance measuring equipment
Note: This is a composite of materials for illustration purposes.

Source: Aeronáutica Civil of the Republic of Colombia, U.S. National Transportation Safety Board and Jeppesen Sanderson

Figure 1*

* This figure is updated from printed issue.

usually built by mentally flying all of the approaches with the goal of detecting and resolving potential problems. Rehearsal of the final plan will help the pilot visualize key elements of the approach.

Many pilots have said that they normally spend 10 minutes to 20 minutes for an approach review into a difficult airport. Some pilots begin this process when they arrive at dispatch or even the night before the flight.

Many of the errors that follow stem from the lack of adequate preparation prior to beginning descent.

4. **An adequate approach briefing was not accomplished.** (***), R, (2112–2126)

Thirteen minutes and 57 seconds elapsed from the beginning of the CVR recording until the flight reported leaving Flight Level (FL) 370 (37,000 feet).

> The only approach items discussed were contained in a comment by the captain at 2123:32: "when you want descent, let me know a few minutes early in case there's a language problem, OK?"
>
> At 2125:40, the first officer said, "well let's see, we got a hundred and thirty six miles to the VOR and thirty two thousand feet to lose, and slow down to boot so we might as well get started."

The purpose of an approach briefing is to exchange information between crewmembers to ensure that both crewmembers are similarly prepared for the approach. The approach briefing is used to identify areas of concern, to clarify the expectations of both crewmembers, to ensure that contributions of each crewmember are considered and to provide a structured time for setting radios and switches for the approach. Briefing is an important skill that enhances *team building* and *team participation.*

An effective briefing should include both nominal and non-nominal items, and should specifically invite feedback from the other crewmember. At Cali, the briefing should have included the previously mentioned approach conditions as well as the planned crossing altitudes and airspeeds over the Cali VOR for the expected instrument landing system (ILS) approach to Runway 01, and over the Tulua VOR for the possibility of a VOR DME [distance-measuring equipment] approach to Runway 19. The VOR DME approach procedure and the aircraft's approximate track are shown in Figure 1.

AA's flight manual requires the captain to brief the crew on which pilot will fly the approach and landing, and to ensure that each crewmember is aware of the type of approach being flown and the intended landing runway. A more detailed approach briefing is required by AA when weather is less than a 1,000-foot (303-meter) ceiling or three miles (five kilometers) visibility. The actual weather was scattered clouds with visibility more than six statute miles (10 kilometers).

Many pilots believe that the content of the briefing should be comprehensive so that attention will be focused on the unique aspects of each approach, not on just a few standard items. Perfunctory briefings can lead to complacency.

5. **The descent checklist was not accomplished.** (**), L, (2112–2141:28)

There is no record of the descent checklist being read during the entire 28 minutes and 59 seconds of the CVR tape.

Checklists are designed to ensure that critical safety-of-flight actions are performed.

An excerpt of the AA B-757 descent checklist from the NTSB Operations Group report is shown in Figure 2.

Excerpt from American Airlines B-757 Normal Procedures Checklist

DESCENT

Prior to Descent Accomplish the First Three Items

FUEL X-FEED SWITCH (EROPS ONLY) .... ON/CHECK/OFF
HSI HDG REF SWITCH .... CHECK IN NORM
PRESSURIZATION .... SET AND CHECKED
SHOULDER HARNESS .... ON
ENGINE AND WING ANTI-ICE .... AS REQUIRED
LANDING DATA .... PREPARED

When Approaching Transition Level

ALTIMETERS .... RESET AND CROSSCHECKED
Set Baro to MSL (QNH)

FL 180 (or 18,000 ft. MSL) or Leaving Cruise Altitude, Whichever Is Lower

LANDING LIGHTS .... ON

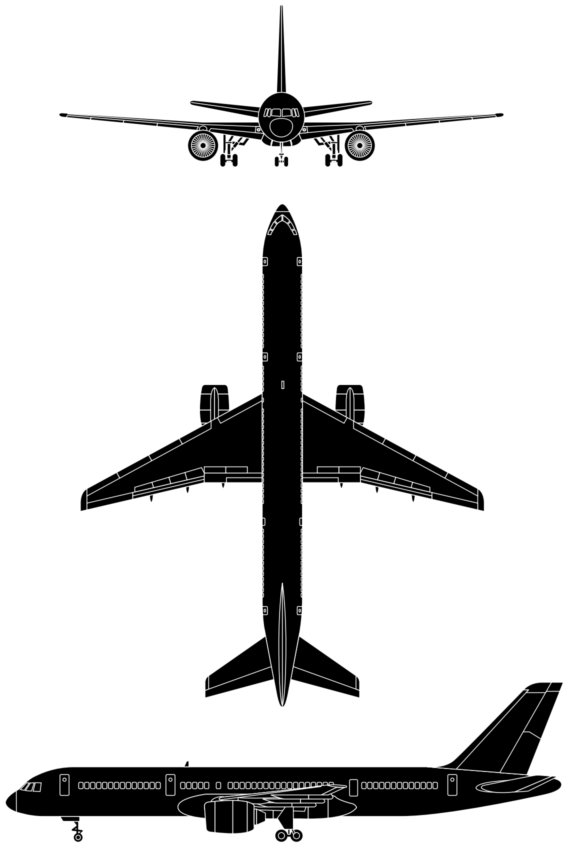
10,000 Ft. MSL (or FL 100)

STERILE COCKPIT .... CHIME

X-Feed = Crossfeed
HSI = Horizontal Situation Indicator
HDG REF = Heading Reference
Norm = Normal
Baro = Barometric Altimeter
MSL = Mean Sea Level

Source: U.S. National Transportation Safety Board

Figure 2



Boeing 757

The Boeing 757-200 series is a medium-range airliner designed to carry 186 passengers in a typical mixed-class configuration. The B-757 can accommodate up to 239 passengers in charter service, putting its capacity between that of the Boeing 737-400 and the Boeing 767. A longer range version and a freighter configuration of the B-757 are also available.

The B-757-200 is powered by two turbofan engines mounted in underwing pods. Engine pairs for the B-757 are provided by Pratt & Whitney (PW 2037 or PW 2040) and Rolls-Royce (535 series). The engines differ slightly in their static thrust.

The aircraft has a maximum takeoff weight of 104,325 kilograms (230,000 pounds) and engine thrust is rated between 170 kilonewtons (38,200 pounds) and 197.1 kilonewtons (43,100 pounds). At maximum takeoff weight with 186 passengers, the B-757 has a range of between 5,222 kilometers (2,820 nautical miles) and 5,519 kilometers (2,980 nautical miles), depending on the engine installed. The B-757 has a top speed of Mach 0.86 and a normal cruising speed of Mach 0.80 and has an initial cruising altitude of about 12,000 meters (40,000 feet).

The two-pilot cockpit of the B-757 has a computerized, fully integrated flight management system (FMS) that provides automatic guidance and control of the aircraft from immediately after takeoff to final approach and landing. The FMS controls navigation, guidance and engine thrust to ensure that the aircraft flies the most efficient route and flight profile.

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

Even though the switches may have been set properly, airline practice requires that the checklist items be read aloud, followed by a "descent checklist completed" statement.

The checklist did not include an item to remind the crew to complete the approach review and briefing. Many airlines specify the completion of the approach briefing as part of the descent checklist. Checklists from the B-757 and older aircraft typically ensure that system controls and switches are set properly. Checklists of newer aircraft also include many of the cognitive tasks that crewmembers perform.

6. **The AA 965 crew did not restate their last position report in their first contact with Cali Approach.** (**), L, (2134:44)

   At 2134:47, the captain transmitted, "ah, buenos noches, señor, American nine six five leaving two three zero, descending to two zero zero. go ahead sir."

   At 2134:55, the controller said, "the uh, distance DME from Cali?"

   At 2134:57, the captain said, "the DME is six three."

   At this time, the flight was approximately 20 nautical miles (37 kilometers) and three minutes north of Tulua descending out of Flight Level 22.5 (22,500 feet).

International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services — Rules of the Air and Air Traffic Services (PANS-RAC) section 14.1.4 states, in part:

> "The last position report before passing from one flight-information region or control area shall be made to the air traffic services unit serving the airspace about to be entered."

AA 965 followed this procedure during the previous initial contact with Bogota Control. When they initiated communication with Cali Approach, the above rule required that the crew give their altitude and their estimated time of arrival over Tulua. Nevertheless, they stated only the altitude. This omission contributed to the misunderstanding of the "cleared to Cali VOR" clearance.

7. **The "cleared to Cali VOR" clearance by Cali Approach was ambiguous.** (**), K, (2134:59)

During the postaccident interview, the controller stated that because the flight crew did not mention in their first contact the routing that they had been cleared to follow, he issued them their clearance to proceed to Cali via the Tulua VOR.

> At 2134:59, the clearance that the controller transmitted was: "roger, is cleared to Cali VOR, uh,

> descend and maintain one, five thousand feet. altimeter three zero zero two. no delay expect for approach. report uh, Tulua VOR."

Although "report … Tulua" suggests ATC's intent that the flight overfly Tulua, the omission of the words "via Tulua" created ambiguity. Language clarity is an essential skill for both controllers and pilots to ensure that the selection of words defines a single meaning.

8. **The route was changed in the FMS without concurrence from the first officer (the pilot flying [PF]).** (**), K, (2135:09)

   > At 2134:59, ATC said, "roger, is cleared to Cali VOR, uh, descend and maintain one, five thousand feet. altimeter three zero zero two ... ."

   > At 2135:09, the FDR indicated that a 6.6-degree roll to the right began, resulting in a heading change of nine degrees — from 189 degrees to 198 degrees.

   > At 2135:09, the controller continued the sentence, "... no delay expect for approach. report uh, Tulua VOR."

Before the controller had finished his sentence and before the crew read back the clearance to ATC, the captain would have had to accomplish the following eight actions: (a) receive the clearance, (b) interpret the clearance, (c) decide to accept the clearance, (d) press the direct intercept key on the FMS control/display unit (CDU), (e) press the line-select key at position 2L on the CDU, (f) press the line-select key at position 6L, (g) verify the provisional (modified) path on the map and (h) press the execute key. After the execute key is pushed, about two seconds elapse before the aircraft begins to turn. Based on FDR and CVR data, the available time of eight seconds was insufficient to accomplish all of these tasks correctly.

This quick action is an indication of *automatic behavior*. Automatic behavior is fast, but it has undesirable side effects. In this situation, the quick action prevented the captain from fully understanding the ATC clearance and from making an informed decision whether or not to accept the clearance. Additionally, the captain's quick action prevented full understanding of the situation by the first officer and precluded him from making any inputs. The first officer may not have recognized that the aircraft was turning.

Most pilots are trained not to push the execute button until the PF has confirmed agreement with the CDU changes. The following sentence is from the *Boeing Flight Crew Training Manual*: "CDU changes should be made by the pilot not flying, and executed only after confirmation by the pilot flying."

> At 2135:28, the captain said, "I put direct Cali for you in there."

Another automatic-behavior error occurred again two and a half minutes later, with far more serious consequences.

9. **The ambiguous clearance was not clarified by the crew.** (**), K, (2135:14)

Safety requires redundancy. Although the primary responsibility for the transmission of correct clearances rests with ATC, pilots must be alert for ATC errors or ambiguities. Crews must be trained to initiate clarifying, questioning and paraphrasing communications about questionable clearances. This behavior begins with the development of a cautious attitude regarding ATC clearances. This is particularly critical where the controller's native language is different from the crew's native language.

Although ATC omitted the words "via Tulua" in the clearance, the captain might have detected the discrepancy between a clearance to Cali VOR and the instruction to report crossing Tulua because Tulua was not on the direct course to Cali.

> Although the captain was not successful in clarifying the ambiguous clearance, at 2123:32, he demonstrated the correct mind-set when he said, "when you want descent, let me know a few minutes early in case there's a language problem, OK?"

> At 2135:14, the captain may have sensed a problem and tried to clarify the situation in his read-back of the clearance, "OK, understood. cleared direct to Cali VOR. uh, report Tulua and altitude one five, that's fifteen thousand three zero zero two. is that all correct, sir?"

Perhaps the captain was experiencing the *confirmation bias*. He might have anticipated an ILS approach that begins at the Cali VOR, then reacted precipitously (by changing the active waypoint to Cali) after hearing the words "to Cali," without recognizing the significance of the disconfirming evidence, "report Tulua."

10. **Approach Control's response to "is that all correct, sir?" was incorrect.** (**), K, (2135:25)

    > At 2135:25, in response to the captain's read-back, Cali Approach transmitted "affirmative."

This response by the controller was incorrect. The captain had added the word "direct" to the original clearance, and the controller apparently missed the word "direct." Active listening is an essential human factors skill for both pilots and controllers.

> In the postaccident investigation, the controller said that the pilot's read-back of the initial clearance was fairly lengthy and ended in a nonstandard expression, "is that all correct, sir?"

By the controller's response of "affirmative" and his reiteration for the pilot to report the Tulua VOR, he believed that they would overfly Tulua, not that they would fly from their present position directly to the Cali VOR.

The effect of the ambiguous clearance and incorrect read-back response was that AA 965 proceeded on a direct course to Cali. Proceeding direct to Cali was not a problem with respect to terrain. The action, however, did cause Tulua (ULQ) to be dropped from the active LEGS page in the CDU. This became a significant factor as soon as the flight was cleared for the approach to Runway 19.

11. **AA 965 accepted an amended approach clearance to Runway 19 without adequate review and evaluation.** (***), K, (2136:40)

At 2136:31, approach said, "* sir, the wind is calm. are you able to approach runway one niner?" [* is an unintelligible word.]

At 2136:36, the captain asked the first officer, "would you like to shoot the one nine straight in?"

At 2136:38, the first officer said, "uh yeah, we'll have to scramble to get down. we can do it."

The flight would have been about one minute north of Tulua descending from 19,100 feet. The distance to the runway would have been approximately 41 nautical miles (76 kilometers). The speed brakes were still retracted. A normal descent in a B-757 would require about 60 nautical miles (111 kilometers) in a clean configuration or about 47 nautical miles (87 kilometers) with the speed brakes extended.

At 2136:40, the captain said, "uh yes sir, we'll need a lower altitude right away though."

Calculating the distance to Runway 01 would have been very quick since the path to Runway 01 already was entered in the FMS. Calculating the distance to Runway 19 also would have been quick if the crew knew how far they were from Tulua and knew that Tulua was 33 miles from Runway 19. But they did not know how far they were from Tulua because Tulua was removed from the LEGS page of the FMS when the activate waypoint was changed from the Tulua VOR to the Cali VOR. Under these circumstances, the crew first would have to determine the distance from the Cali VOR to the approach end of Runway 19 and then subtract this number from the distance shown on the DME to the Cali VOR. Determining the distance from the Cali VOR to the approach end of Runway 19 would require the identification of three different distances on the ILS Runway 01 approach chart (Cali VOR to the final approach fix [FAF], FAF to the middle marker and middle marker to Runway 01), the identification of runway length on the airport chart, the conversion of the runway length (in feet) into nautical miles, and the addition of the three distances and the runway length.

Although there was insufficient time to make the calculations, the crew accepted ATC's suggestion. Recognize that repeated favorable experience with ATC suggestions, as is common in many parts of the world, can breed complacency unless counteracting training has been provided.

Thus, human factors training must expose crews to the time-based structure of piloting and the need to make decisions prior to high-workload periods.

The captain's responsibility for the highest degree of safety should have led either to a decision to decline the offer to land straight in or to request a 360-degree turn while the aircraft was above the grid minimum off-route altitude (MORA).

The human inability to cope with distractions during a rushed approach became apparent.

The determining factor of the runway-change decision should have been whether or not the new approach could be conducted without excessive workload, fixation or distraction. This requires an assessment of numerous factors including approach difficulty, prior preparation, crew experience and adequate distance to establish an unrushed and stabilized approach.

The runway-change decision should have been supported by effective monitoring. Monitoring by the PNF is much more than a fill-in activity. Monitoring requires, among other things, the performance of all of the cognitive tasks the PF is doing and the ongoing assessment of how and when to intervene. Thus, the captain would have to be familiar with the physical features of the Cali area and the geometry of the VOR DME approach to Runway 19, and would have to have recognized that the aircraft was too high, too fast and too close to the runway for an unrushed and stabilized approach. The expected descent path normally would have been decided during the approach review and entered into the FMS but could be determined in real time using simple calculations for descent and deceleration (such as one nautical mile per 10 knots of deceleration and three nautical miles per 1,000 feet for descent). Effective monitoring would also require that pilot workload and attention state receive equal consideration.

After the decision was made to accept the change to the VOR DME approach to Runway 19, the human inability to cope with distractions during a rushed approach became apparent.

12. **The "cleared for approach" clearance by Cali Approach did not contain an altitude restriction.** (**), K, (2136:43)

At 2136:40, the captain said, "uh yes sir, we'll need a lower altitude right away though."

At 2136:43, Cali Approach said, "roger. American nine six five is cleared to VOR DME approach runway one niner. Rozo number one, arrival. report Tulua VOR."

This clearance was ambiguous. The crew requested a lower altitude, but the controller cleared the flight for an approach. This phraseology opened the door for the confirmation bias.

A more accurate clearance would have been for Cali Approach to state explicitly the altitude restriction that existed prior to Tulua, i.e., "cleared for the VOR DME approach to runway one niner, *maintain one five thousand feet until Tulua*."

13. **The "cleared for approach" clearance was not clarified with respect to altitude changes.** (**), K, (2136:52)

Although Cali Approach may not have transmitted an accurate clearance, the crew is nevertheless responsible for clarifying ambiguities. Apparently, the crew did not recognize the discrepancy between their request for a lower altitude and the clearance for an approach.

At 2136:52, the captain said, "cleared the VOR DME to one nine, Rozo one arrival. will report the VOR, thank you sir."

At 2136:58, Cali Approach said, "report uh, Tulua VOR."

At 2137:01, the captain said, "report Tulua."

At 2137:59, the first officer said, "OK, so we're cleared down to five now?"

The captain said, "that's right ..."

This interpretation error may have been influenced by the confirmation bias. The crew requested and believed that they would quickly receive a clearance for a lower altitude. The immediate response by ATC with a clearance for the approach to Runway 19 confirmed this belief. The approach clearance was accepted as a clearance to descend, without challenge, because of the natural association of descents and approach clearances.

14. **The crew requested an improper clearance to Rozo.** (**), K, (2137:29)

At 2137:29, the captain said, "can American Airlines uh, nine six five go direct to Rozo and then do the Rozo arrival sir?"

This request by the crew was contrary to ATC procedures. The following paragraph is extracted from the *Aeronautical Information Manual* (*AIM*) (5-4-7-e):

"Except when being radar vectored to the final approach course, when cleared for a specifically prescribed IAP [instrument approach procedure], i.e., 'cleared ILS runway one niner approach' or when 'cleared approach,' i.e., execution of any procedure prescribed for the airport, pilots shall execute the entire procedure commencing at an IAF [initial approach fix] or an associated feeder route as described on the IAP chart unless an appropriate new or revised ATC clearance is received, or the IFR flight plan is canceled."

Cali is situated in a valley bordered by high terrain and demonstrates why this paragraph is in the *AIM*. The only way to make a safe instrument approach to Runway 19 is to pass over Tulua and fly the 202-degree radial so that the aircraft will fly above the valley and between the high terrain.

A request for a nonstandard clearance might be misinterpreted or automatically approved — regardless of legality — where controllers do not question the captain's requests.

15. **Approach Control's response to AA 965's request to go direct to Rozo was incorrect.** (**), K, (2137:36)

Cali Approach replied to AA 965's request by transmitting, "affirmative. take the Rozo one and runway one niner, the wind is calm."

This response was incorrect. Cali Approach should have said, "negative" and then repeated or clarified the instructions.

Cali Approach meant for the flight to execute the Rozo One Arrival, a charted standard instrument-arrival route. This arrival requires aircraft to overfly Tulua before proceeding to Rozo via the Tulua 202-degree radial and the Cali VOR 13-degree radial.

The use of the word "affirmative" allowed the confirmation bias to influence again the crew's decision.

16. **The ambiguous clearance was not clarified by the crew.** (**), K, (2137:42–2137:53)

Although the clearance was ambiguous, the crew could have recognized the discrepancy between their request to proceed direct to the Rozo NDB and ATC's clearance to fly the Rozo One Arrival to Runway 19. If the discrepancy had been recognized, the clearance could have been clarified and the flight would not have attempted to go directly to Rozo.

The confirmation bias, however, probably interfered with the crew's ability to analyze the clearance. The captain wanted to proceed direct to Rozo and interpreted "affirmative" as confirmation of his request without carefully analyzing the remainder of the sentence.

The communication between the crew and the controller continued with neither party recognizing that the other had a different interpretation of the clearance.

> At 2137:42, the captain said, "alright Rozo, the Rozo one to one nine, thank you, American nine six five."
>
> At 2137:46, ATC said, "(thank you very much) ... report Tulua and eeh, twenty-one miles, ah, five thousand feet."
>
> At 2137:53, the captain said, "OK, report Tulua twenty-one miles and five thousand feet, American nine, uh, six five."

Cali Approach expected the flight to proceed to Tulua and then via the Rozo One Arrival, while the captain planned to proceed direct to Rozo and then fly the balance of the Rozo One Arrival.

17. **The SELECT DESIRED WPT (waypoint) information on the display screen was not user friendly.** (**), R, (2137:36–2137:43)

During the captain's readback of the Rozo clearance, "R," the published identifier for the Rozo NDB was entered into the direct intercept page. The CDU responded with two SELECT DESIRED WPT pages of waypoints named R — 12 in all. Each R was identified as an NDB and the 17-character latitude and longitude coordinates of the NDB. The 12 Rs were listed from top to bottom according to their distance from the aircraft. The first R would have appeared as follows:

R NDB
N 04°40.8 W 074°06.3

The captain could have compared the waypoint latitude and longitude coordinates shown on the CDU with the Rozo latitude and longitude coordinates published on the chart of the Rozo One standard terminal arrival route (STAR). If the chart for the Rozo One STAR was not readily available, the captain could have approximated the coordinates for Rozo by using the latitude and longitude marks on the left side and bottom of the plan view on the Jeppesen Sanderson VOR DME Runway 19 approach chart. The process, however, would require time and could be subject to error.

After the identifier "NDB" on the SELECT DESIRED WPT page, display of the NDB name, such as "Rozo" or "Romeo," would make the process user friendly.

18. **The captain did not verify the latitude and longitude on the FMS SELECT DESIRED WPT page.** (**), K, (2137:36–2137:43)

Perhaps, because of time constraints in comparing latitude and longitude coordinates during approach, the captain apparently assumed that the closest R would be Rozo and selected the top waypoint on the page without verifying the coordinates. The closest waypoint is usually at the top of the SELECT DESIRED WPT page; but in this accident, the waypoint at the top of the page was for the Romeo NDB — the incorrect waypoint for the approach. The coordinates of Rozo are (N 03° 35.8 W 076° 22.5); the coordinates of Romeo are (N 04° 40.8 W 074° 06.3).

The captain's selection was incorrect.

19. **The FMS database and the charted database were different.** (***), R, (2137:42–2137:53)

Unknown to the crew, the R selected identified the Romeo NDB at Bogota at their eight o'clock position, approximately 132 nautical miles (244 kilometers) away.

Colombia has two NDBs with an R identifier, both with the same frequency of 274 kHz. According to Aeronautical Radio Inc. (ARINC) 424/ICAO naming conventions, two waypoints in the same geographical area should not have the same name in the navigational database. Thus, the Romeo NDB in Bogota could be accessed by entering its chart identifier, R, in the FMS SELECT DESIRED WPT page. The Rozo NDB, however, could be accessed only by entering its full name, ROZO, in the SELECT DESIRED WPT page.

Although the crew tried to access the Rozo NDB in the FMS by entering the identifier (R) for the NDB that is shown on the chart, the FMS did not include Rozo among the 12 Rs in the SELECT DESIRED WPT pages.

The charted and FMS databases must present identical information to the crew.

20. **The captain did not verify the provisional path on the FMS map display before executing the change.** (***), S, (2137:36–2137:43)

When the top waypoint on the SELECT DESIRED WPT page was selected, the FMS would have displayed a white-dashed provisional (modified) path from the aircraft's position to the selected waypoint, Romeo. The purpose of this provisional path is to permit the crew to verify that the new path is the desired path before pushing the execute button. The provisional path would have shown a 110-degree turn to the left, but apparently the captain did not verify the provisional path. This assumption is strengthened by a review of the timing of the following events.

> The Cali Approach transmission, "affirmative, take the Rozo one and the runway one niner, the wind is calm," began at 2137:36 and the aircraft began to turn at 2137:43 — seven seconds later.

Because one second to two seconds are required for the provisional path to change to the active path and cause the initiation of the turn, the execute button probably was pushed before the above sentence was completed.

This error is another indication of automatic behavior. Pilots can make very quick path changes and sometimes neglect to verify the provisional path before execution. This behavior is consistent with the captain's previous behavior of making quick entries without sufficient verification of the data for the new path. Human factors training programs must discuss the human tendency for automatic behavior and the need to slow down and verify all path changes.

21. **The captain did not ask the first officer to confirm the path change before executing the change.** (***), K, (2137:36–2137:43)

After the provisional path is verified by the crewmember making the change in the CDU, the path should be confirmed by the other pilot. This is essential to keep the PF aware of all FMS changes and to ensure that both pilots' independent perspectives are considered. Moreover, if FMS changes are made without the PF's knowledge, the PF could become disoriented.

The first officer was not asked to confirm any change and was not informed about any change during the remaining three minutes and 38 seconds of the flight. If he had been asked to confirm the path change, the abnormal provisional path might have been detected.

At 2137:59, the first officer was reviewing the approach chart and apparently did not detect the change in aircraft heading for about one minute after the beginning of the turn. When he did detect the change, he became confused about the aircraft's position and apparently did not regain an awareness of his geographical position. His comments for the balance of the flight indicate the debilitating effect of this *concept shift.* Consider the time (three minutes and 38 seconds) that the first officer was disoriented.

> The first indication of the first officer's confusion came at 2138:49 — 66 seconds after the beginning of the turn — when he said, "uh where are we ..."
>
> At 2138:52, he continued, "we goin' out to ..."
>
> At 2138:54, the captain said, "let's go right uh, Tulua first of all, OK?"
>
> At 2138:58, the first officer said, "yeah, where we headed?"
>
> At 2139:04, the first officer said, "manual," as he selected the HDG SEL (heading select) mode on the FMS.
>
> At 2139:05, the captain said, "let's come to the right a little bit."
>
> At 2139:06, the first officer said, "... yeah he's wantin' to know where we're headed."
>
> At 2139:30, the first officer said, "left turn, so you want a left turn back around to ULQ."
>
> At 2139:32, the captain said, "nawww ... hell no, let's press on to ..."
>
> At 2139:35, the first officer said, "well we're, press on to where though?"
>
> At 2140:52, after the captain's offer to "put it in the box if you want it," the first officer said, "I don't want Tulua. let's just go to the extended centerline of uh ... Rozo."

The aircraft was more than nine nautical miles (17 kilometers) off course.

The standard process of requiring PF concurrence before FMS changes are executed is essential for maintaining time-and-space awareness, and must be reinforced by human factors training.

22. **The crew did not detect and correct, in a timely manner, the aircraft's deviation from the cleared path.** (***), K, (2136:40–2141:15)

The primary task for the PF is to control the flight path of the aircraft. The PNF also has an important responsibility to monitor the flight path. Neither of these tasks was performed adequately during the period from 2137:43 to 2141:15. During most of this period, the aircraft was traveling about 500 feet per second. At one time, the aircraft was more than nine nautical miles (17 kilometers) off course.

The reason for the deviation is traceable to the decision to accept a new clearance in the midst of an approach. This decision placed the crew in a rushed situation requiring the accomplishment of numerous tasks in a very brief period. These tasks could have been manageable if the crew had anticipated and prepared for the tasks. Many tasks were performed during this period, and some were overlapping. For example:

- Receive and read back clearance. (2136:43 to 2136:52)
- Clarify clearance with ATC. (2136:58 to 2137:01)

- Discuss the intent of the clearance. (2137:03 to 2137:27)
- Mentally calculate the descent profile. (?[unknown])
- Decide on the need for speed brakes and deploy speed brakes. (? to 2137:25)
- Get out approach pages. (2137:10 to 2137:12)
- Review approach. (2137:25 to ?)
- Request clearance to Rozo. (2137:29 to 2137:53)
- Enter new approach into FMS. (? to 2137:43)
- Tune ADF [automatic direction finder] to Rozo and VOR to ULQ. (2138:01 to 2139:29)
- Discuss altitude and approach. (2137:59 to 2138:33)
- Receive and respond to ATC altitude request. (2138:39 to 2138:49)
- Question aircraft position. (2138:49 to 2139:58)
- Discuss what ULQ is. (2138:58)
- Discuss aircraft position and track (2139:04 to 2139:19)
- Change MCP (FMS mode control panel) from LNAV (lateral navigation) to HDG SEL. (2139:10)
- Identify (?)VC. (2139:22 to 2139:25)
- Retune and identify ULQ. (2139:25 to 2139:29)
- Discuss aircraft position and track. (2139:30 to 2139:56)
- Transmit to ATC about position and reclarification of clearance. (2140:01 to 2140:27)
- Perform MCP heading knob action. (2140:08)
- Comments (by the captain) about headings. (2140:24 to 2140:35)
- Discuss problems about receiving Tulua. (2140:40 to 2140:59)
- Request to get QFE (height above field elevation) altimeter settings and set altimeters. (2141:00 to ?)
- Perform MCP change to vertical-speed mode and then IAS mode. (2141:11)
- Receive and respond to ATC altitude query. (2141:02 to 2141:10)
- Respond to GPWS warnings. (2141:15 to 2141:21)

The most significant period was the first 15 seconds to 30 seconds after the aircraft began the turn toward Romeo (2137:43 to 2138:22). After this period, the crew would have had difficulty detecting the aircraft's deviation from the correct course because of the confusion associated with the concept shift.

The combination of (a) the decision to accept the VOR DME approach to Runway 19, (b) the resulting number of additional tasks that needed to be performed and (c) the limited time resulting from the too-high, too-fast, too-close-in aircraft position contributed to the development of a hazardous situation. These three items provided opportunities for distraction from the crew's primary responsibility to monitor and control the flight path of the aircraft.

23. **The crew did not discontinue the approach when they were rushed, confused and uncertain about their position.** (***), K, (2137:03–2141:28)

Even though the crew was not aware of their position, they should have been aware of their physical sensations and emotional feelings about the approach. They were rushed, disoriented and confused.

These conditions should have signaled the crew to discontinue the approach and proceed direct to Cali. This was the time to put the MORA or minimum safe altitude (MSA) to use — by staying above it.

A flight crew might not take corrective action in a stressful situation, however, unless the crew has been previously trained to recognize haste, disorientation and confusion, and to react in a very specific manner. If human factors training including line-oriented flight training (LOFT) simulation has not specifically trained the crew for this recovery situation, they might continue trying to resolve their confusion instead of discontinuing the approach.

This normal tendency to try to resolve confusing situations is seen in the captain's behavior.

> At 2139:25, he said, "OK, I'm getting it. seventeen seven. just doesn't look right on mine. I don't know why."
>
> The first officer said, "left turn, so you want a left turn back around to ULQ."
>
> The captain said, "nawww ... hell no, let's press on to ..."

The first officer said, "well we're, press on to where though?"

The captain said, "Tulua."

At 2139:40, the captain said, "where we goin'? one two ... come to the right. let's go to Cali. first of all, let's, we got # up here didn't we." [# is an expletive.]

The first officer said, "yeah."

At 2139:46, the captain said, "go direct … CLO [Cali VOR] ... how did we get # up here?"

A few seconds later, he said, "come to the right, right now, come to the right, right now."

The first officer said, "yeah, we're, we're in a heading select to the right."

The captain then said to Cali Approach, "and American uh, thirty eight miles north of Cali, and you want us to go Tulua and then do the Rozo uh, to uh, the runway, right? to runway one nine?"

Approach said, "you can * landed, runway one niner, you can use runway one niner, what is altitude and DME from Cali?"

At 2140:21, the captain said, "OK, we're thirty seven DME at ten thousand feet."

After a few other remarks, at 2140:34, the captain said, "come to the right, come come right to Ca-Cali for now, OK?"

The first officer said, "OK."

At 2140:40, the captain said, "it's that # Tulua I'm not getting for some reason." A few seconds later, he said, "see I can't get, OK now, no, Tulua's # up."

The first officer said, "OK. yeah."

Consider the time during which the captain apparently felt compelled to resolve the problem instead of discontinuing the approach. His preoccupation with Tulua may have been because of the influence of the *recency bias* or the *availability heuristic*. That is, he could have been biased by his previous attempt to tune Tulua, recent reports of sabotage to VOR stations in Colombia, or recent reports of "map-shift" problems in South America. (A map shift is a sluing of the navigation display that usually is caused by inaccurate survey data in the FMS database.)

Metacognitive skills are an important part of human factors training. Pilots must be trained to recognize when they are rushed, confused or disoriented and take prompt recovery action — especially if they are below the nearby terrain.

24. **AA 965 descended from 15,000 feet before it was on a segment of the approach.** (**), K, (2138:43)

"Cleared for the approach" does not mean "cleared to descend." Cleared for the approach means that the crew is cleared to execute an IAP. If the approach procedure authorizes a lower altitude, the segment during which the descent is authorized will be indicated on the approach chart. The VOR DME Runway 19 approach chart authorizes descent only after the aircraft has passed Tulua and is established on the 202-degree radial of Tulua.

The applicable rule can be found in the *AIM* (5-4-7-b), which states:

> "When operating on an unpublished route or while being radar vectored, the pilot, when an approach clearance is received, shall, in addition to complying with the minimum altitudes for IFR operations (FAR Part 91.177), maintain the last-assigned altitude unless a different altitude is assigned by ATC, or until the aircraft is established on a segment of a published route or IAP."

Pilots must be trained to recognize when they are rushed, confused or disoriented and take prompt recovery action.

The FDR indicated descent below 15,000 feet at 2138:43. Because the aircraft was never established on the 202-degree radial of Tulua, the crew should have maintained 15,000 feet.

At 2137:59, the misinterpretation of the ATC procedures was evident when the first officer said, "OK, so we're cleared down to five now?"

The captain said, "that's right, and ... off Rozo … which I'll tune here."

[This type of error also occurred in the Trans World Airlines CFIT accident at Washington (D.C., U.S.) Dulles International Airport in 1974. TWA Flight 514, a Boeing 727, was cleared by ATC for the VOR DME Runway 12 approach. The flight crew initiated a descent to the initial approach altitude, 1,800 feet, before the aircraft had reached the approach segment where that minimum altitude applied. The aircraft struck a mountain about 25 nautical miles (46 kilometers) northwest of the airport. The 92 occupants were killed.[3]]

If we are to learn lessons from past accidents, crews must be provided with explanatory information about the errors involved in these accidents.

25. **The crew did not report descending from 15,000 feet.** (*), L, (approximately 2138:43)

Notwithstanding the requirement to maintain 15,000 feet until the aircraft was established on the 202-degree radial of Tulua, the crew should have reported descending from 15,000 feet.

The *AIM* (5-3-3-a) states:

> "The following reports should be made to ATC or FSS [flight service station] facilities without a specific ATC request: 1. At all times: (a) When vacating any previously assigned altitude or flight level for a newly assigned altitude or flight level."

If the crew had reported descending from 15,000 feet, ATC might have realized that the aircraft had not yet reported passing Tulua.

26. **The crew did not disengage the autothrottle after the GPWS warning.** (**), S, (2141:15–2141:28)

AA's B-757/767 operating manual states, in part:

> "If a [GPWS] Mode-2 'Terrain! Terrain!' warning occurs, immediately and simultaneously:
>
> - "Advance power to maximum available while disengaging autothrottle, if engaged; and,
> - "Rotate smoothly at a normal rate to an initial target pitch attitude of 15 degrees while disconnecting autopilot, if engaged; then continue to 20 degrees pitch. If stick shaker occurs, stop rotation and use stick shaker boundary as upper limit of pitch. Always honor stick shaker. A wings-level pull-up should be made unless terrain being avoided can be seen, since any angle of bank will decrease climb capability."

The FDR indicated that the autopilot was disconnected during the recovery maneuver and that the engines bean to accelerate from flight idle at a rate consistent with rapid advancement of the throttles. Nevertheless, the FDR indicated that the autothrottle was not disconnected.

27. **The speed brakes were not retracted.** (**), R, (2141:15–2141:28)

> At 2141:15, the GPWS sounded, "terrain, terrain, whoop, whoop ..."
>
> At 2141:17: the captain said, "oh #."
>
> At 2141:15, the CVR recorded a sound similar to the beginning of an autopilot disconnect warning.
>
> At 2141:18, the captain said, " ... pull up baby."
>
> At 2141:19, the GPWS sounded, " ... pull up, whoop, whoop, pull up."
>
> At 2141:20, the CVR recorded a sound similar to the aircraft stick shaker.
>
> At 2141:20, the first officer said, "it's OK."
>
> At 2141:21, the GPWS sounded, "pull up."
>
> At 2141:21, the captain said, "OK, easy does it, easy does it."
>
> At 2141:22, the CVR recorded a sound similar to the autopilot disconnect warning; the sound similar to the aircraft stick shaker stopped.
>
> At 2141:23, the first officer said, "(*nope*)" [Italics indicate a questionable insertion in the transcript.]
>
> At 2141:24, the captain said, "up baby … "
>
> At 2141:25, the CVR recorded a sound similar to the aircraft stick shaker; the sound continues to impact.
>
> At 2141:25, the captain said, " ... more more."
>
> At 2141:26, the first officer said, "OK."
>
> At 2141:26, the captain said, "up, up, up."
>
> At 2141:27, the GPWS sounded, "whoop, whoop, pull up."
>
> The recording ended at 2141:28.

Pitch control appeared to be in accordance with the published procedure. After increasing thrust, the PF increased pitch until it was limited by the stick shaker.

The GPWS emergency procedure did not account for extended speed brakes. Because the GPWS procedure did not specify that the speed brakes should be retracted, the crew could not be expected to retract the speed brakes automatically; they followed their training.

The GPWS procedure does not specify any monitoring duties for the PNF. The captain had not been specifically tasked to verify that the autothrottle was disengaged and that the speed brakes were retracted, which would have ensured that the aircraft's performance would have been increased during the pull-up.

This is a *rule-based mistake*; the crew followed the rule, but the rule was in error.

Specific Training Strategies Can Help Prevent CFIT Accidents

AA has the benefits of modern technology and is staffed with dedicated instructors and crewmembers. Statements collected by the NTSB from co-workers indicated that the crew of AA965 was competent, professional and well-respected. The B-757 has a very positive safety record. Fatigue and stress were not identified as contributing factors in the accident. How, then, is it possible for this accident to have occurred?

The analysis thus far suggests that 25 major errors and two minor errors might have contributed to this accident. If any of the major errors had not occurred, the accident might have been prevented. If two or three of these errors could have been prevented, the accident most likely would not have occurred. Of the 25 major errors, 18 (72 percent) were attributable to actions or omissions by the flight crew, five (20 percent) were attributable to actions or omissions by ATC and two (eight percent) were attributable to design.

James Reason's taxonomy[4] offers insight into some of the causal factors. Three of the major errors are *lapses*, two are *slips*, four are rule-based mistakes and 16 are *knowledge-based mistakes*. Slips and lapses are often caused by inattention, but rule-based mistakes and knowledge-based mistakes are related to knowledge deficiencies that often can be corrected by more effective training.

Because most of the errors were actions or omissions by the flight crew, the remainder of this analysis will focus on the 18 major flight-crew errors.

One method of analyzing the flight-crew errors is to consider each error from an interpersonal (between persons) or intrapersonal (individual) perspective. That is, does the error represent a failure of group interaction skills, or does it represent a failure of individual cognitive skills? Cognitive skills are the thinking, planning, attending, strategizing, preparing and remembering parts of flying. This analysis is shown in Table 1. If an error could be considered from both perspectives, the primary perspective is marked with an "X" while the secondary perspective is marked with an "O."

Table 1 implies a significant dichotomy: Although most CRM training has been interpersonal training, the errors in the Cali accident were mostly intrapersonal.

Table 1
Error Perspective

Crew Error		Interpersonal	Intrapersonal
3	Inadequate approach review		X
4	Inadequate approach briefing	O	X
5	Descent checklist not accomplished		X
6,14, 24	Published ATC rules not followed		X
8, 21	Provisional path not confirmed by PF	X	O
9,13, 16	ATC clearance not clarified	O	X
11	Accepted rushed approach to RW 19		X
18	"R" latitude-longitude not checked		X
20	Provisional path to "R" not verified		X
22	Heading and lateral position not monitored		X
23	Approach not discontinued		X
26	Autothrottle not disengaged		X
27	Speed brakes not retracted		X

Interpersonal Errors = Errors involving group dynamics and interaction.

Intrapersonal Errors = Individual crewmember errors including the thinking, planning, attending, strategizing, preparing and remembering parts of flying.

Source: David A. Simmon

The importance of the intrapersonal perspective and the cognitive skills is evident in the Cali accident:

> **Complacency**, to some extent, can be inferred in errors 3, 4, 5, 6, 8, 9, 11, 13, 14, 16, 20, 21, 22, 23 and 24. The reader should view complacency as a normal consequence of the learning process, however, and not as an individual trait or character deficiency. Complacency can be considered an undesirable side effect of overlearned and automatic behavior. Nevertheless, complacency can be controlled by experience or training.
>
> **Cognitive biases** are evident in errors 9, 13, 16 and possibly 23. The confirmation bias (errors 9, 13 and 16) was especially insidious because the crew looked only for confirming evidence; they ignored contradictory evidence and became satisfied after confirming evidence was found.
>
> **Fixation**, also known as absorption, one of the four hazardous states of attention (the other three are distraction, preoccupation and overload), is evident in error 22. Fixation is also a factor in errors 11 and 14.
>
> **Inattention** is also a factor with all of the slips and lapses — errors 5, 6, 20, 22 and 26.
>
> **Reasoning and problem-solving mistakes** can be found in errors 11, 13, 14, 16, 18, 20 and 23.

Most pilots, over time, develop satisfactory intrapersonal skills without training. Nevertheless, specific intrapersonal training should be developed and presented to all pilots to increase awareness of human error and the counteracting strategies that can reduce human error. For example, a one-day intrapersonal human factors training program could include:

1. Human-error training — training to understand the causes and characteristics of lapses, slips, mistakes, biases, complacency, the hazardous thought patterns and the hazardous states of attention.

2. Skills and strategy training — training to introduce the crewmember to effective thought patterns, time-based skills, remembering skills, attention-management skills, reasoning and problem-solving skills, physiological skills to enhance mental state, team-building skills and team-participation skills.

Another useful way of analyzing crew errors is to consider the type of training that would have been needed to eliminate the error. For this purpose, four types of training are presented: (a) flying skills (psychomotor), (b) technical knowledge and procedures, (c) interpersonal skills (CRM), and (d) individual cognitive skills. This analysis is shown in Table 2 on page 16. The most important training area is indicated with an "X," and the secondary training areas are shown with an "O."

Table 2 (page 17) contains a broader, more comprehensive set of criteria. The Tech column indicates the need for specific knowledge and procedures to combat most of the errors. This type of training is highly specific to the particular error and can be considered specific safety training. For example, to train flight crews to clarify ambiguous ATC clearances, an airline might:

1. Catalogue numerous ambiguous clearances;

2. Train crews in the classroom to detect the ambiguous clearances;

3. Train crews in the classroom to resolve clearance ambiguities with clarifying, questioning and paraphrasing communications; and,

4. Reinforce the classroom training by introducing ambiguous clearances during simulator LOFT periods.

Specific safety training is effective because the crew is trained to cope with a particular threat. In contrast, current CRM training usually discusses communications only in a general sense. Additionally, current CRM training often lacks operational context and the necessary level of specificity to change behavior.

An apparently common industry belief is that behavior can be reliably controlled by blanket, high-level instructions. This misconception, which is implicit in most airline training, is flawed in two respects:

First, high-level instructions do not go deeply enough to provide sufficient specific detail to guide behavior. Training specifies the desired crew behavior but does not specify the technique to be used to achieve the desired behavior. In effect, training tells pilots what to do but does not always tell them how to do it. The distinction between "what" and "how to" is simply a decision to limit the description of a prescribed behavior to a less-detailed description that can omit significant details. A how-to at one level of detail becomes a what at the next level of detail. Carried to its extreme, this method would simply instruct the crew to "fly the airplane safely." This process should not have an arbitrary cutoff but should be continued until sufficient detail is provided to produce the behavior desired.

The second flaw is the assumption that blanket instructions can control behavior. A fundamental tenet of psychology is that behavioral control requires positive feedback at the appropriate level of specificity and at the appropriate time. Blanket instructions do not fulfill this requirement. To control crew behavior effectively and reliably, training must:

Table 2
Training Area to Eliminate Error

Errors		Flying	Tech	Inter	Cognt
3	Inadequate approach review		O		X
4	Inadequate approach briefing		O	O	X
5	Descent checklist not accomplished		X		O
6,14, 24	Published ATC rules not Followed		X		O
8, 21	Provisional path not confirmed by PF		X	O	O
9,13, 16	ATC clearance not clarified		O	O	X
11	Accepted rushed approach to RW 19		O		X
18	"R" latitude-longitude not checked		O		X
20	Provisional path to "R" not verified		X		O
22	Heading and lateral position not monitored	O	O		X
23	Approach not discontinued		X		O
26	Autothrottle not disengaged		X		O
27	Speed brakes not retracted		X		O

Flying = Flying skills (psychomotor).
Tech = Technical knowledge and procedures.
Inter = Interpersonal skills involving group dynamics and interaction
Cognt = Cognitive skills involving the individual thinking, planning, attending, strategizing, preparing and remembering parts of flying.

Source: David A. Simmon

- Provide sufficient motivational information to persuade crewmembers that a particular behavior is needed;
- Provide a detailed description of the desired behavior;
- Provide opportunities for both guided and independent practice; and,
- Provide appropriate reinforcement and positive feedback through human factors training, LOFT, technical training and checking activities to ensure that the desired behavioral skills are appropriately developed and retained.

The most important lesson from Table 2 is that integrated human factors training is needed. That is, no discipline should be taught in isolation. Technical knowledge, procedures training and cognitive training must be integrated into one training package. Thus, the previous example regarding the training of flight crews to clarify ATC clearances is not complete until two more cognitive items are added:

5. Crews must be preconditioned with basic human-error training that will make them aware of their own susceptibility to error, and the skills and strategies that can counteract human-error susceptibility; and,

6. Crews must be preconditioned with effective thought-pattern training. This training is essential for crews to develop a cautious, wary and suspicious thought pattern regarding all ATC clearances.

Crews will be able to detect and resolve ambiguous clearances only when these last two items are combined with the previous four. Error prevention will not be effective without both types of training.

Human factors training will always be better if it is operationally oriented. Consider the training that would be needed to eliminate error 11 — the decision to accept the new clearance to Runway 19. Consider the difference if specific safety training incorporating the appropriate cognitive skills were developed for accepting new approaches. The following elements could be integrated into a coordinated, operational-training package:

1. Effective thought-pattern training (intrapersonally oriented) to help crews develop a cautious, wary and suspicious thought pattern regarding all ATC clearances. That is, the first thought after the receipt of any clearance would be, "Given my current situation, is it appropriate for me to accept this clearance?";

2. Basic human-error training (intrapersonally oriented) to ensure that crews will be aware of their own susceptibility to human error and of the skills and strategies that can be used to counteract human error. The undesirable effects of overload and absorption (fixation) and the time-based structure of piloting should be stressed. Crews should learn specific time-based remembering and attention-management skills to counteract overload and fixation;

3. Specific monitoring training (intrapersonally oriented) to ensure that the PNF mentally performs the same cognitive tasks as the PF as well as an ongoing assessment (interpersonally oriented) of how and when to intervene;

4. Assertiveness and constructive-confrontation training (intrapersonally oriented) to ensure that the important contributions of both crewmembers will be considered whenever there are differences of opinion; and,

5. Specific airline technical guidance (technical training) regarding the specific rules, procedures and techniques to be used to stay within policy guidelines. These rules would specify the roles of the PF as well as the monitoring role of the PNF. Crews would be trained to give primary consideration to the attention states of other crewmembers.

Each of the errors in the Cali accident can be trained out of existence — one at a time — by the same methodology. The key is to integrate both intrapersonal and interpersonal skills into operationally oriented training modules.

Strategies to prevent a CFIT accident include flight-crew training in the following areas:

1. Making a thorough mental review of the characteristics of every takeoff and approach;

2. Performing a comprehensive briefing for every takeoff and approach. The briefing should be tailored for the specific takeoff or approach, and the briefing should include both expected and unexpected items. The pilot conducting the briefing should explicitly request feedback from the other pilot;

3. Properly completing all checklists. Airlines should consider including the approach review and briefing as part of the descent checklist;

4. Correctly following ATC rules and procedures, especially those that could relate to CFIT accidents;

5. Detecting ambiguous clearances and resolving them with questioning, paraphrasing and clarifying communications;

6. Carefully evaluating runway changes by ATC. Changes should be refused unless the crew is prepared mentally for the new approach and can accomplish the new tasks without becoming distracted or absorbed. New approaches should be rejected unless the crew is confident that they can make a stabilized approach;

7. Verifying the appropriateness of CDU changes and obtaining confirmation of the changes by the PF before executing the changes;

8. Ensuring that one pilot always is monitoring and controlling the flight path of the aircraft;

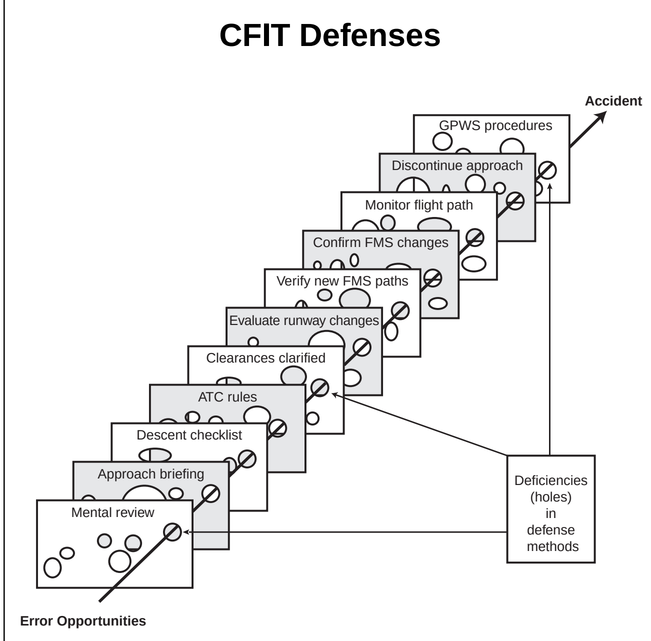
9. Discontinuing the approach whenever disorientation, confusion or uncertainty of position occurs; and,

10. Quickly and accurately applying the manufacturer's GPWS procedures in the event of a GPWS warning. The PNF should ensure performance of the correct procedures.

These strategies are defenses against a potential CFIT accident. Figure 3 (page 19), which is adapted from an accident-causation model developed by James Reason, illustrates these defenses. These defenses, however, are not perfect and may contain some deficiencies — shown as holes in Figure 3. For this reason, it is important for airlines to improve continually each of these defenses through training. This action will reduce the deficiencies and begin to close the holes.

Training Must Include Appropriate Context, Perspective, Content and Detail

The Cali accident is an industry problem. Accordingly, it is the responsibility of national regulatory authorities and senior airline managements to ensure that human factors programs contain the appropriate concepts and mix of skills. This means that the content of human factors training programs, including advanced qualification programs, and their specific training objectives must undergo careful scrutiny. To record that human factors training has been completed is insufficient action. Responsible persons must ensure that human factors programs include *both* the interpersonal perspective *and* the intrapersonal perspective; and that they include *both* individual cognitive skills *and* teamworking skills. Expertise from cognitive psychologists



Source: David A. Simmon

Figure 3

as well as social psychologists should be applied as required. Human factors training must include appropriate perspectives, comprehensive content and an appropriate level of detail, and it must always be applied within an operational context.

Cognitive training is especially needed by pilots operating aircraft with advanced flight-management and information-display systems. Pilots in older aircraft like the Boeing 727 and the McDonnell Douglas DC-9 are constantly reminded of the need to master a complete set of individual cognitive skills. In newer, "glass-cockpit" aircraft with full-mission automation capability, it is possible to fly an entire flight without appropriate thinking, planning, attending, strategizing, preparing or remembering as long as the pilot has learned to push the right buttons. Unanticipated events, however, require specific intervention skills to resolve problems. Training must be applied to ensure that all flight crews master these basic, individual, cognitive airmanship skills.

Further research is needed to identify ways to prevent and counteract human error. This research should focus on the development of expert levels of attention-management skills, time-based skills, remembering skills, effective thought patterns, reasoning and problem-solving skills, physiological factors to enhance mental state, team-building skills and team-participation skills.♦

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Capt. David A. Simmon (retired) has been involved with aviation for more than 45 years and has more than 15,000 hours of flight time. He began his aviation career in the U.S. Air Force and in the Colorado (U.S.) Air National Guard, flying F-80, F-86 and F-100 aircraft. Simmon was a pilot for United Airlines for 35 years, flying numerous aircraft, from the Douglas DC-6 to the Boeing 747-400. He held several management positions at United, including manager of B-727 flight standards and training, and director of flight safety. Simmon cowrote a CFIT curriculum advisory manual for Transport Canada and has presented numerous papers on safety and human factors. *The author expresses his appreciation to Alan Pope, Ph.D., of National Aeronautics and Space Administration Langley Research Center in Hampton, Virginia, U.S., and to Charlotte Freeman, Ph.D., of Samford University in Birmingham, Alabama, U.S., for their assistance with this article.*

Cockpit Voice Recorder Transcript, American Airlines Flight 965 Dec. 20, 1995

2104:00	**BOG:**	report ready for descent and please squawk code alpha two three one four.[1]
2104:??	**RDO-1:**	OK squawk two two one four uh and report ready for descent, gracias.
2104:??	**BOG:**	de nada.
2112:29	**CAM-1:**	alright quickly if I can get in there. if not, I'll be right back.
2119:20	**CAM:**	[click similar to cockpit door being operated]
2119:30	**CAM-1:**	any messages?
2119:31	**HOT-2:**	well we did get the weather, it's good.
2119:33	**CAM-1:**	alright.
2119:40	**CAM-1:**	she's claiming they they get an extra, twenty minutes.
2119:46	**HOT-2:**	an extra twenty minutes, for what?
2119:49	**CAM-1:**	debri … , it's, it's difficult with the language problem, but …
2119:55	**CAM-1:**	umm, according to her figures, they're not legal to report to the airport till eight fifty. if we get in at ten o'clock, now I'm figuring about ten o'clock, * round it out. eight fifty for a nine … fifty, departure. she says it's their legality. so I said well OK, if that's the case maybe what we'll do is we'll go, leave the hotel at eight fifty, get to the airport at nine twenty, and depart at nine fifty. and that * roughly the plan right now. I want to see what they have to say about, cause she says their duty rigs are slightly different than ours. first she said they have a forty-five minute debrief which would have been fifteen extra minutes, then she said, they needed twenty extra minutes, rather than a half hour, cause I don't know where the hell she's comin' up with that but … anyway. with this stuff, you're not only worried about # over your crew, but you really have to worry about what's legal FAAwise, because …
2121:02	**HOT-2:**	yeah.
2121:03	**CAM-1:**	… if you don't have your legal rest … you have the new rigs there?
2121:07	**HOT-2:**	I got this little chart but …
2121:08	**CAM-1:**	well you see what you come up with. I'll watch the airplane and the radio, OK?
2121:11	**HOT-2:**	OK.
2121:50	**HOT-2:**	all I see on this little chart they handed out, is on duty time but it's not …
2121:56	**CAM-1:**	that's another very confusing thing, that …
2121:59	**HOT-2:**	but it doesn't say anything about rest period.
2122:02	**CAM-1:**	I started to say, I wrote this little sheet out, I called tracking one day and I said hey, this # international is doing me, and I don't understand two man crew blah, blah, blah, it varies two man crew, three man … I said, I want you to spell out the legal rest, and that's where I got this from. and I wrote it down very explicitly. ten hours minimum crew rest.
2122:28	**HOT-2:**	that's on international?
2122:29	**CAM-1:**	yeah, if you fly less than five and a half hours.
2122:32	**HOT-2:**	which this case …
2122:33	**CAM-1:**	that's our scenario. ten hours crew rest, thirty minute debrief, and one hour sign in. and you can't move that up at all, because it's an FAA thing. you roll those wheels, before eleven and a half hours, you're #. now, now, like I say. I can, I'll have you know, grab a little extra half hour for us. we'll report a little bit late. just give us a little extra sleep time. as long as we get the thing off at nine fifty so we don't get, get our ass **, why the # didn't you report. to which I will say, the thirty forty minute # cab ride each way I don't think we had enough legal safe time now if you want to hang me on that you hang me on that but I didn't break any FAA regulations anyway you know.
2123:32	**CAM-1:**	when you want descent, let me know a few minutes early in case there's a language problem, OK?
2123:37	**HOT-2:**	sure.
2123:38	**CAM-1:**	I can get through.
2123:45	**HOT-1:**	now, I'll attempt the company here the next few minutes, get a little bit closer.
2124:12	**HOT-2:**	yeah, see this is about the right length trip. it feels like it's about time to land now …
2124:15	**HOT-1:**	yep.
2124:18	**HOT-2:**	… you know we're on these eight and a half hour deals *.
2124:19	**HOT-1:**	too much.
2124:19	**HOT-2:***	miserable the last four hours.
2124:21	**HOT-1:**	I am. I don't know how some guys do it so much. you know **?

2124:25 **HOT-2:** yeah, I flew with *.

2124:26 **HOT-1:** yeah * a friend of mine. I played tennis, with him. an uh, he used to fly that Sao Paulo and all of that # all the time … well you know in * last five years and, and all that, # * you're # killin' yourself doin' that #. you really need that extra couple hundred bucks, a month or whatever it comes to retirement? but anyway uh … to each his own. but he said he didn't mind it, he didn't mind driving back home at five o'clock in the morning, but to me I'm like …

2124:58 **HOT-2:** yeah.

2125:00 **HOT-1:** … it's torture.

2125:01 **HOT-2:** yeah.

2125:02 **HOT-1:** torture in the # car, trying to keep awake and stay alive, uh uh. I discussed this with my wife, I said honey I just don't want to do this, I hope you don't feel like I'm *. she said no way, forget it. she said, you don't need to do that #.

2125:20 **HOT-1:** [sound similar to yawn]

2125:23 **HOT-1:** yeah, * just retired a couple weeks ago.

2125:25 **HOT-2:** yeah, I knew this was his last month.

2125:27 **HOT-1:** yeah. he's a good man. I like *. we're good friends.

2125:31 **HOT-2:** he got robbed at knife point in Rio, wasn't it?

2125:33 **HOT-1:** that's right. he got stuck a little bit actually too.

2125:40 **HOT-2:** well let's see, we got a hundred and thirty six miles to the VOR, and thirty two thousand feet to lose, and slow down to boot so we might as well get started.

2125:49 **HOT-1:** alright sir.

2126:01 **HOT-1:** and if if you'd keep the speed up in the descent, I'd, it would help us too, OK?

2126:04 **HOT-2:** OK.

2126:16 **RDO-1:** Bogota, American nine six five request descent.

2126:20 **BOG:** American nine six five, descend and maintain flight level two four zero, report reaching.

2126:26 **RDO-1:** OK, we're leaving three seven zero. descend and maintain two four zero, twenty four. thank you ma'am. American nine six five.

2126:33 **BOG:** that's correct.

2126:35 **HOT-2:** twenty four set.

2126:35 **HOT-1:** yes sir.

2126:40 **HOT-1:** I'm goin' to call the company.

2126:42: **HOT-2:** OK.

2126:42 **RDO-1:** American airlines operations at Cali, this is American nine six five, do you read?

2126:49 **OPS:** go ahead American nine six five, this is Cali ops.

2126:51 **RDO-1:** alright Cali. we will be there in just about twenty five minutes from now eeh, and go ahead the weather.

2127:00 **OPS:** OK sir, the the change over, the temperature is twenty * degrees. the altimeter, the (QNH) is two nine point nine eight. conversion is two six point seven one.

2127:18 **RDO-1:** OK, understand the weather is good. twenty three degrees, two nine nine eight. two six seven one. is that correct?

2127:24 **OPS:** that's correct.

2127:25 **RDO-1:** OK, are we parking at gate two tonight?

2127:28 **OPS:** gate two and uh runway (zero) one.

2127:32 **RDO-1:** runway zero one roger and the weather is good, huh?

2127:34 **OPS:** OK captain.

2127:36 **RDO-1:** see you on the ground, nine six five.

2127:39 **HOT-1:** two nine nine eight, two six seven one. that sounds about right, let's see. three twenty six. nine nine eight, three two six is two seven six, uh, right on the money. OK, that's good. uhhhh, the weather's good. runway one, gate two.

2127:58 **HOT-2:** alright. ***

2127:59 **HOT-1:** alright baby.

2127:59 **HOT-2:** sounds good.

2128:00 **HOT-1:** alright.

2128:05 **HOT-1:** and I'm gonna put the headlights on early here because there's a lot of VFR and who knows what good deal. so the headlights might just help us a little bit.

2128:23 **HOT-1:** and also … what was that position was five? we're just about at it, aren't we?

2128:27 **HOT-2:** yeah. forty seven north of Rio Negro uh, 'course we didn't go to Rio Negro.

2128:33 **HOT-1:** sorry?

2128:35 **HOT-2:** talking about the uh …

2128:36 **HOT-1:** yeah, it was Rio Negro plus forty seven I think …

2128:38 **HOT-2:** Rio Negro plus forty seven.

2128:39 **HOT-1:** … what's, what they show lat long?

2128:41 **HOT-2:** well, let me find it.

2128:42 **HOT-1:** just out of curiosity, five something.

2128:45 **HOT-2:** I had the flight plan.

2128:46 **HOT-1:** alright, * I wouldn't worry about it.

2128:56	**HOT-2:**	there we go.
2128:57	**HOT-2:**	north uh, zero five one four six. four, so zero five forty one …
2129:00	**HOT-1:**	we're passed it. OK, we're passed it, we press on, right?
2129:04	**HOT-2:**	right.
2129:15	**HOT-1:**	I'm going to talk to the people.
2129:17	**HOT-2:**	OK.
2129:18	**HOT-1:**	I'm off.
2129:23:	**PA-1:**	uh ladies and gentlemen, this is captain …, we have begun our descent for landing at Cali. it's a lovely evening as we had expected. we'll pass a shower or two on the way in but uh, at the field right now it's uh, good visibility. the temperature is two three, that's twenty three degrees Celsius, and if you prefer Fahrenheit, that's seventy two degrees on the Fahrenheit scale. the winds are ten miles an hour from the north west. it's a very very pretty evening. I'd like to thank everyone for coming with us. again, I apologize for, being late tonight. these things do happen sometimes, very frustrating but there wasn't very much we could do about it. again I appreciate your patience in the matter. like to wish everyone a very very happy holiday, and a healthy and prosperous nineteen ninety six. thank you for coming with us.
2130:14	**HOT-1:**	I'm back.
2130:28	**HOT-2:**	uh I may have to slow down if it gets too rough.
2130:30	**HOT-1:**	sure.
2131:08	**HOT-1:**	you want any of these nuts, Don?
2131:09	**HOT-2:**	no thank you.
2131:11	**HOT-1:**	you want me to call for the water or do you want to wait till we get on the ground, 'bout your water?
2131:14	**HOT-2:**	oh, I'll get it on the ground.
2131:22	**HOT-2:**	one to go.
2131:25	**HOT-1:**	aye, aye.
2131:29	**HOT-1:**	you got the engine heat off good.
2131:53	**RDO-1:**	American nine six five is level two four zero.
2132:11	**RDO-1:**	American nine six five is level two four zero.
2132:13	**BOG:**	standby two minutes for lower.
2132:21	**HOT-1:**	pretty night, huh?
2132:23	**HOT-2:**	yeah it is, lookin' nice out here.
2133:25	**HOT-2:**	let's see, what is the transition level here?
2133:28	**HOT-1:**	oh yeah, it's a good check.
2133:32	**HOT-2:**	eighteen thousand?
2133:33	**HOT-1:**	one ninety, eighteen thousand, yeah.
2133:40	**HOT-2:**	well if she doesn't let us down in a little while, she's goin' to put me in a jam here.
2133:50	**RDO-1:**	and American nine six five, request lower.
2133:53	**BOG:**	American nine six five. * descend to flight level two zero zero. report leaving two four zero.
2133:59	**RDO-1:**	we're leaving two four zero now and descending to two zero zero.
2134:03	**HOT-2:**	it's set.
2134:04	**BOG:**	call Cali frequency one one niner decimal one. buenos noches.
2134:07	**RDO-1:**	please say the frequency again.
2134:09	**BOG:**	one one niner decimal one.
2134:13	**RDO-1:**	one one niner decimal one. feliz navidad, seniorita.
2134:15	**BOG:**	muchas gracias, lo mismo.
2134:19	**RDO-1:**	gracias.
2134:22	**RDO-1:**	center, American nine six five, leaving flight level two four zero descending to two zero zero. buenos tardes.
2134:37	**HOT-2:**	nineteen one or …
2134:39	**HOT-1:**	that's Cali.
2134:40	**RDO-1**:	Cali Approach, American nine six five.
2134:44	**APR**:	American niner six five, good evening. go ahead.
2134:47	**RDO-1**:	ah, buenos noches señor, American nine six five leaving two three zero, descending to two zero zero. go ahead sir.
2134:55	**APR**:	the uh, distance DME from Cali?
2134:57	**RDO-1**:	the DME is six three.
2134:59	**APR:**	roger, is cleared to Cali VOR, uh, descend and maintain one, five thousand feet. altimeter three zero zero two … .
2135:09	**HOT-2**:	one five.
2135:09	**APR**:	… no delay expect for approach. report uh, Tulua VOR.
2135:14	**RDO-1**:	OK, understood. cleared direct to Cali VOR. uh, report Tulua and altitude one five, that's fifteen thousand three zero … zero … two. is that all correct sir?
2135:25	**APR**:	affirmative.
2135:27	**RDO-1**:	thank you.
2135:28	**HOT-1**:	I put direct Cali for you in there.
2135:29	**HOT-2**:	OK, thank you.

2135:44	**HOT-2**:	two fifty below ten here?
2135:47	**HOT-1**:	yeah.
2136:18	**CAM**:	[sound of single chime similar to seat belt switch being activated]
2136:20	**PA-1**:	uh, flight attendants please prepare for landing, thank you.
2136:24	**HOT-1**:	I sat'em down and …
2136:27	**APR**:	* niner six five, Cali.
2136:28	**PA-1**:	niner.
2136:29	**RDO-1**:	niner six five, go ahead please.
2136:31	**APR**:	* sir the wind is calm. are you able to approach runway one niner.
2136:36	**HOT-1**:	would you like to shoot the one nine straight in?
2136:38	**HOT-2**:	uh yeah, we'll have to scramble to get down. we can do it.
2136:40	**RDO-1**:	uh yes sir, we'll need a lower altitude right away though.
2136:43	**APR**:	roger. American nine six five is cleared to VOR DME approach runway one niner. Rozo number one, arrival. report Tulua VOR.
2136:52	**RDO-1**:	cleared the VOR DME to one nine, Rozo One arrival. will report the VOR, thank you sir.
2136:58	**APR**:	report uh, Tulua VOR.
2137:01	**RDO-1**:	report Tulua.
2137:03	**HOT-1**:	I gotta give you to Tulua first of all. you wanna go right to CAL, er to Tulua?
2137:09	**HOT-2**:	uh, I thought he said the Rozo One arrival?
2137:10	**HOT-1**:	yeah, he did. we have time to pull that out(?) …
2137:11	**CAM**:	[sound similar to rustling pages]
2137:12	**HOT-1**:	… and, Tulua One … Rozo … there it is.
2137:25	**HOT-1**:	yeah, see that comes off Tulua.
2137:27	**HOT-2**:	OK.
2137:29	**HOT-1**:	can American Airlines uh, nine six five go direct to Rozo and then do the Rozo arrival sir?
2137:36	**APR**:	affirmative. take the Rozo One and runway one niner, the wind is calm.
2137:42	**RDO-1**:	all right Rozo, the Rozo One to one nine, thank you, American nine six five.
2137:46	**APR**:	(thank you very much) … report Tulua and eeh, twenty-one miles, ah, five thousand feet.
2137:53	**RDO-1**:	OK, report Tulua twenty-one miles and five thousand feet, American nine uh, six five.
2137:59	**HOT-2**:	OK, so we're cleared down to five now?
2138:01	**HOT-1**:	that's right, and … off Rozo … which I'll tune here.
2138:26	**HOT-1**:	see what I get.
2138:27	**HOT-2**:	yeah.
2138:28	**HOT-1**:	… at twenty-one miles at five thousand's part of the approach, okay?
2138:31	**HOT-2**:	OK.
2138:33	**HOT-1**:	off ULQ, so let me put ULQ in here, seventeen seven cause I want to be on raw data with you.
2138:39	**APR**:	American niner six five, distance now?
2138:42	**RDO-1**:	uuuh, what did you want sir?
2138:45	**APR**:	distance DME.
2138:46	**HOT-1**:	OK the distance from uh, Cali is uh, thirty-eight.
2138:49	**HOT-2**:	uh where are we …
2138:49	**APR**:	roger.
2138:52	**HOT-2**:	we goin' out to …
2138:54	**HOT-1**:	let's go right to uh, Tulua first of all, OK?
2138:58	**HOT-2**:	yeah, where we headed?
2138:58	**HOT-1**:	seventeen seven, ULQ uuuh, I don't know what's this ULQ? what the, what happened here?
2139:04	**HOT-2**:	manual.
2139:05	**HOT-1**:	let's come to the right a little bit.
2139:06	**HOT-2**:	… yeah he's wantin' to know where we're headed.
2139:07	**HOT-1**:	ULQ. I'm goin' to give you direct Tulua.
2139:10	**HOT-2**:	OK.
2139:10	**HOT-1**:	… right now.
2139:11	**HOT-1**:	OK, you got it?
2139:13	**HOT-2**:	OK.
2139:14	**HOT-1**:	and …
2139:18	**HOT-1**:	it's on your map. should be.
2139:19	**HOT-2**:	yeah, it's a left uh, left turn.
2139:22	**HOT-1**:	yeah, I gotta identify that # though I …
2139:25	**NAV-1**:	[sound of Morse code (for) VC, "dit dit dit dah, dah dit dah dit"]
2139:25	**HOT-1**:	OK, I'm gettin' it. seventeen seven. just doesn't look right on mine. I don't know why.
2139:29	**NAV-1**:	[sound of Morse code, similar to ULQ, "dit dit dah dit dah dit dit dah dah dit dah dit"]
2139:30	**HOT-2**:	left turn, so you want a left turn back around to ULQ.

2139:32	**HOT-1**:	nawww … hell no, let’s press on to …
2139:35	**HOT-2**:	well we’re, press on to where though?
2139:37	**HOT-1**:	Tulua.
2139:39	**HOT-2**:	that’s a right u u.
2139:40	**HOT-1**:	where we goin’? one two … come to the right. let’s go to Cali. first of all, let’s, we got # up here didn’t we.
2139:45	**HOT-2**:	yeah.
2139:46	**HOT-1**:	go direct ... C ... L ... O. how did we get # up here?
2139:54	**HOT-1**:	come to the right, right now, come to the right, right now.
2139:56	**HOT-2**:	yeah, we’re, we’re in a heading select to the right.
2139:59	**RDO-1**:	[sound of click]
2140:01	**RDO-1**:	and American uh, thirty-eight miles north of Cali, and you want us to go Tulua and then do the Rozo uh, to uh, the runway, right? to runway one nine?
2140:11	**APR**:	***, you can * landed, runway one niner, you can use, runway one niner. what is (you) altitude and (the) DME from Cali?
2140:21	**RDO-1**:	OK, we’re thirty-seven DME at ten thousand feet.
2140:24	**HOT-1**:	you’re OK. you’re in good shape now.
2140:25	**APR**:	roger.
2140:26	**HOT-1**:	we’re headin’…
2140:27	**APR**:	report (uh) five thousand and uh, final to one one, runway one niner.
2140:28	**HOT-1**:	we’re headin’ the right direction, you wanna …
2140:32	**HOT-1**:	# you wanna take the one nine yet?
2140:34	**HOT-1**:	come to the right, come come right to CA Cali for now, OK?
2140:35	**HOT-2**:	OK.
2140:40	**HOT-1**:	it’s that # Tulua I’m not getting for some reason.
2140:44	**HOT-1**:	see I can’t get, OK now, no, TULUA’s # up.
2140:48	**HOT-2**:	OK. Yeah.
2140:49	**HOT-1**:	but I can put it in the box if you want it.
2140:52	**HOT-2**:	I don’t want Tulua. let’s just go to the extended centerline of uh …
2140:55	**HOT-1**:	which is Rozo.
2140:56	**HOT-2**:	Rozo.
2140:56	**HOT-1**:	why don’t you just go direct to Rozo then, all right?
2140:58	**HOT-2**:	OK, let’s …
2140:59	**HOT-1**:	I’m goin’ to put that over you.
2141:00	**HOT-2**:	… get some altimeters, we’re out of uh, ten now.
2141:01	**HOT-1**:	all right.
2141:02	**APR**:	niner six five, altitude?
2141:05	**RDO-1**:	nine six five, nine thousand feet.
2141:10	**APR**:	roger, distance now?
2141:15	**CAM-4**:	terrain, terrain, whoop, whoop…
2141:17	**HOT-1**:	oh #.
2141:17	**CAM**:	[sound similar to autopilot disconnect warning starts.]
2141:18	**HOT-1**:	… pull up baby.
2141:19	**CAM-4**:	… pull up, whoop, whoop, pull up.
2141:20	**CAM**:	[sound similar to aircraft stick shaker]
2141:20	**HOT-2**:	it’s OK.
2141:21	**CAM-4**:	pull up.
2141:21	**HOT-1**:	OK, easy does it, easy does it.
2141:22	**CAM**:	[sound similar to autopilot disconnect warning and sound similar to aircraft stick shaker stops.]
2141:23	**HOT-2**:	(nope)
2141:24	**HOT-1**:	up baby …
2141:25	**CAM**:	[sound similar to aircraft stick shaker starts and continues to impact]
2141:25	**HOT-1**:	… more, more.
2141:26	**HOT-2**:	OK.
2141:26	**HOT-1**:	up, up, up.
2141:27	**CAM-4**:	whoop, whoop, pull up.
2141:28	end of recording	

HOT	=	Crew member hot microphone voice or sound source
RDO	=	Radio transmission from accident aircraft
CAM	=	Cockpit area microphone voice or sound source
APR	=	Radio transmission from Cali Approach Control
PA	=	Transmission made over aircraft public address system
BOG	=	Radio transmission from Bogota Area Control Center
OPS	=	Radio transmission from American Airlines Cali operations.
-1	=	Voice identified as captain
-2	=	Voice identified as first officer
-?	=	Voice unidentified
*****	=	Unintelligible word
#	=	Expletive
( )	=	Questionable insertion
[ ]	=	Editorial insertion
…	=	Pause

[1] CVR transcript begins at 2112:29. Communications at 2104 transcribed by Aeronáutica Civil of the Republic of Colombia.

Other Parties' Submissions to the Official Accident Investigation Report Provide Details Behind Errors

American Airlines

Aids to navigation. AA reviewed the difficulty experienced by the accident flight crew in locating the Rozo nondirectional beacon (NDB) in the flight management computer (FMC) database. In its comments, AA said that "selecting 'R' provides the pilots [with a list of] 12 navigational aids, listed ... according to distance from the airplane, with the closest listed first, next closest second, and so forth. Rozo was not one of the navigational aids listed in the 'R' category. Romeo, which was [244 kilometers (132 miles)] northeast, was the first navigational aid listed. In the FMC navigational database, the identifier for Rozo is 'ROZO.'"

"To understand the significance of these mismatched naming conventions, one can compare Rozo to other navaids in the vicinity of Cali. To select Cali VOR, its identifier (CLO) is entered. To select Tulua VOR, its identifier (ULQ) is entered. To select Buenaventura VOR, its identifier (BUN) is entered. And to select the fix the crew obtained in error, Romeo NDB Bogota, its identifier (R) is entered.

"But to select Rozo NDB, its name must be entered. Rozo and Rozo appear[ed] on their respective charts in exactly the same way, a box identifier with the name above and the frequency and identifier in the box. … Yet, one appear[ed] in the database by identifier and the other by its name."

The AA report continued, "The differences in charts and [computer] displays result from two different sets of standards for charts and electronic data. Approach charts are driven by the individual country's procedure for that approach. The country defines the fixes and names them as [it sees] fit, presumably within ICAO [International Civil Aviation Organization] limits. These are then displayed on charts using the Jeppesen format and standards, or those of any other chart provider.

"Navigation data bases are governed by a set of conventions (ARINC 424) [see "Aeronautical Radio Inc.," page 26] that have been developed and revised over a 23-year period. These standards govern the selection of fixes to be displayed for any procedure and provide a convention for naming fixes.

"Applied to approaches, these [ARINC] standards lead to several relevant points. ... Rozo is not displayed because it is used only as a step-down fix," the AA report said. "Fixes that are used solely for step-downs are eliminated in the [FMC] database in order to prevent 'snaking' of the final approach course and clutter of the display. …

"This process results in the end users, the pilots, being presented with a real-time transition task in a high-workload phase of the flight. Even if the pilot fully understands the fix selection and naming conventions, he or she must still translate between what is in the chart and what is displayed by the FMC display. Pilot translation between charted and displayed information for an approach is a significant source of distraction, workload and potential error. Either the database should match the chart, or the chart should include fix names as displayed in the navigational data."

AA accessed the database of a B-757 simulator and selected seven navigational aid identifiers beginning with the letter "R." The results showed that "none of these selections provided Rozo as a choice," the AA report said. "These navigational aids are only identified on the FMC waypoint pages by their latitude and longitude.

"Therefore, the only way to ensure that the navigational aid sought by the pilot is the one displayed to the pilot, as his requested selection, is for the pilot to compare the displayed vs. desired waypoint latitude and longitude. The geographic latitude/longitude coordinates do not appear on the approach charts. ...

"Runway changes ... increase workload by requiring pilots to locate new charts, retune navaids, reidentify navaids, brief the new approach and reset [altitude] minimums bugs," the report said. "Making such changes on an FMC-equipped aircraft greatly increases workload. ...

"The disadvantage lies in prioritizing the time and steps necessary to change the FMC against the immediate need to control the course of the aircraft and prepare the pilots and navigational radios to fly the approach."

AA training emphasizes that entries into automated flight systems be verified immediately. "An input entered into an autoflight system, an FMC entry or an autopilot-command selection must be cross-checked against its result," the AA report said. "In this case, preparing for the approach was given higher priority. The most significant pilot role in this accident surrounds this misplaced priority. In a moment of task saturation, both pilots gave priority to the wrong task."

The AA report said, "From the beginning of the (left) turn off course until the first officer called for 'altimeters' just prior to

Aeronautical Radio Inc. (ARINC)

ARINC is an international corporation whose principal stockholders are airlines, air transport companies and aircraft manufacturers.

ARINC operates a system of domestic and overseas aeronautical land radio stations, fulfills systems requirements to accomplish ground and airborne compatibility, allocates and assigns radio frequencies to meet those needs, and coordinates standard airborne communications and electronic systems.♦

the GPWS [ground-proximity warning system] warning, neither crewmember specifically mentioned terrain. Though the captain communicated some concern with the situation when directing a turn to the right, and the first officer expressed at least frustration in proposing they set aside ULQ and fly to the [Runway] 19 centerline, neither pilot intervened to change the vertical path of the aircraft.

"Well documented in human factors literature is the basic human tendency to focus on prominently displayed or readily available information identified as 'figure' over less prominent or [less] available information identified as 'ground.' Attention is brought to bear on objects or information that capture our focus.

"In this [accident] situation, course information is prominently displayed on navigation displays and arrival and approach charts. Terrain information (beyond simple peaks) is displayed only on the area chart, which would tend to be set aside when initiating an arrival. Attention is more readily drawn to desired course than to terrain to be avoided. Navigation displays may have exacerbated this tendency by increasing the salience of course information without a corresponding increase in terrain display.

"A second well-documented human tendency is to escalate commitment to, rather than abandon, a course of action when difficulties are encountered. Among pilots flying ... automated aircraft this can be manifested in attempts to correct an 'automation-induced' deviation by manipulating the automated system, rather than the controls of the aircraft. ... They could instead revert to a lower level of automation, including hand flying. … There is great motivation to understand why the autoflight system did not work as expected and to make it perform.

"The misprioritization of preparing for the approach over cross-checking the result of direct 'R' may reflect an inappropriate use of, and level of trust in, flight path automation. The crew of Flight 965 trusted enough in the function of the FMC and their understanding of it to turn away to set up the new approach.

"In the subsequent 60 seconds, the aircraft turned [more than] 90 degrees, and was already (unknown to the crew) substantially off course. In this short period of time, the crew momentarily lost their awareness of where they were and where they wanted to be."

Communications. AA investigators reviewed the communications between Cali Approach and the accident flight. "At 2134:59, Cali Approach … issued the following clearance to [Flight] 965: 'roger, is cleared to Cali VOR, uh, descend and maintain one, five thousand feet, altimeter three zero zero two … no delay expect for approach. report uh, Tulua VOR,'" the AA report said. "This clearance was not consistent with the ICAO Document 4444, *Rules of Air Traffic and Air Traffic Services* … . Those references advise that in order to be valid, a clearance should have a route of flight such as via a route and/or reporting point(s), via a flight planned route or via an arc or a DME [distance measuring equipment] station."

At 2138:45, Cali Approach requested Flight 965's distance from Cali, which the crew reported as 38 DME (70 kilometers [38 nautical miles]). "During this period of time, the controller was using the telephone normally located at the supervisor's desk, which was to the right and about [1.8 meters (six feet)] from his control position," the AA report said.

"According to Aeronáutica Civil's ATC [air traffic control] transcript, at 2138:50, the controller acknowledged Flight 965's transmission that they were at 38 DME; simultaneously, as quoted from the ATC tape transcript, the following events occurred: 'Background music and rhythmic tapping.' Nonpertinent telephone conversation, initiated by the Cali controller at 2139:48, ended at 2140:03, concurrent with 'we're' in the next [AA] transmission."

Commenting on the language difficulties between the accident flight crew and the Cali Approach controller, the AA report said that "insufficient language ability played a role in the crew's and controller's understanding of the clearance direct to CLO [Cali] and in the controller's inability to communicate that some of [Flight] 965's reports and requests were not understood. ...

"The controller was concerned about some of the position reports. CLO DME readings of [70 kilometers and 69 kilometers (38 nautical miles and 37 nautical miles)] are south of [Tulua] ... . One minute and 35 seconds had elapsed in which the airplane reported covering only one mile. However, the controller reported that he could not formulate his concerns into English to communicate them to the crew. …

"Given the miscommunications between the captain and controller during the final minutes of the flight, one must question whether the language requirements and phraseology used under ICAO standards provide pilots and controllers with enough common language for both to participate in problem-solving."

Ground-proximity warning system (GPWS) escape maneuver. The AA report commented on the crew's action following the GPWS warning: "The first officer, who was the pilot flying, responded to the GPWS terrain warning within one second. He pitched the airplane nose-up at a rate of three [degrees] to four degrees per second to a 20-degree attitude and disconnected the autopilot. Approaching 20 degrees pitch attitude, the angle-of-attack triggered the stick shaker.

"With autothrottles engaged in the speed mode, the throttles advanced. The EPR [engine-pressure ratio] commands reached the thrust-limit target of 1.752 EPR after approximately six seconds elapsed time. At impact, after 9.2 seconds elapsed time, the actual engines EPRs only attained 1.182 and 1.348 for the left and right engine respectively. ...

"At 20 degrees pitch attitude, the first officer 'honored' the stick shaker by pushing forward on the yoke. This action lowered the angle-of-attack sufficiently to stop the stick shaker. Subsequently, the first officer pitched the nose up again into and through stick-shaker angle-of-attack and on to stall angle-of-attack. The pitch attitude peaked at 31 degrees. This sequence of events clearly demonstrated the inadequacy of the stick shaker as the primary indicator for angle-of-attack. …

"Prior to impact, the aircraft had been descending at a rate of approximately [458 meters (1,500 feet)] per minute, negative six degrees [angle of attack], three degrees pitch attitude and a calculated airspeed of [444 kilometers per hour (kph) (240 knots)]. It had gone from a 20-degree bank right turn, through wings level and on to 13-degree bank left turn moments before impact. The airplane reached a pitch attitude of 31 degrees and angle-of-attack of 14 degrees (nose-up) during the escape maneuver. ... During the escape maneuver, the airspeed decreased to [346 kph (187 knots)].

The AA report reviewed the effects of the deployed speed brakes on the crew's ability to avoid a collision with terrain: "The performance group's report showed that stowing the speed brakes and using the stick shaker as an angle-of-attack indicator may provide an additional altitude gain of approximately [46 meters (150 feet)] … . However, the structures group survey stated that initial tree strikes began approximately [76 meters (250 feet)] below the ridgeline. Therefore, the stowage of the speed brakes alone would not have allowed the airplane to avoid the mountain.

"The performance group study did show that if the speed brakes were stowed and the airplane was flown at constant stick-shaker optimum angle-of-attack, it would have achieved an additional gain of about [92 meters (300 feet)], which would have been sufficient to clear the ridgeline and the trees. In this study, the 'math pilot' is effectively using an angle-of-attack indicator to maintain maximum coefficient of lift.

"The installation of a functional, user-friendly, angle-of-attack indicator in all transport category airplanes, in combination with training, would enable pilots to extract maximum available performance from their airplane. This would be equally valuable in all escape maneuvers, regardless of the initiator. ...

"All transport category airplanes already have angle-of-attack systems installed. Therefore, this recommendation involves no new technology; it merely suggests that angle-of-attack, the most significant indication of any wing's performance, be presented to the pilot in a usable form."

The AA report commented on the need for the development of an enhanced ground-proximity warning system (EGPWS): "Depending on altitude and terrain gradient, EGPWS would as much as double the warning time in seconds relative to the current GPWS. The most significant factor influencing climb performance and altitude gain is time, prior to potential terrain impact, that the escape maneuver starts. Combined with GPS [global positioning system] to drive its navigational database, it is a dramatic improvement over its predecessor. It has been demonstrated to [AA] and is being actively pursued."

Wreckage and impact information. The AA report commented on the location of the accident site in the Aeronáutica Civil accident report: "The closest known coordinates [of the accident site] are based on a [GPS] position on the west side of the mountain ridge derived by the [AA] team. This position does not exactly agree with other positions from a variety of sources; nor has it been possible to positively correlate that GPS position with a topographical map.

"Therefore, the exact latitude and longitude of the initial impact with the trees on the east side of the mountain is not known. Based on limited time on the scene and difficult weather and terrain conditions, the wreckage diagram in the structures report is abbreviated and should not be considered complete."

In its report, AA said that the probable causes of the accident were: "(1) inadequacies of the [accident aircraft] FMC's navigational database, and failure of those responsible to ensure that the database matched conventional published/charted information and reflected ARINC 424 advisories; (2) the flight crew's failure to perceive the FMC-initiated turn away from the intended routing; and (3) the approach controller's inadequate English-language abilities and his inattention during a critical phase of the approach.

"Contributing to the causes of the accident were: (1) lack of radar coverage; (2) approach control clearances that were not in accordance with ICAO standards; (3) the flight crew's increased task overload caused by the unexpected change in the assigned runway for the approach; and (4) the manufacturer's/vendor's overconfidence in FMC technology and the resultant influence passed onto pilots regarding the FMC's capabilities."

AA, based on its participation in the accident investigation, recommended:

- "That FAA [the U.S. Federal Aviation Administration] develop requirements for the installation of a functional angle-of-attack indicator in all transport category airplanes. This should become a certification requirement for all future airplanes and a retrofit for existing fleets;
- "That FAA develop requirements for the installation of [EGPWS] on all transport category airplanes. This should become a certification requirement for all future ... airplanes and a retrofit for existing fleets;
- "That ICAO remind member countries to follow established air traffic control guidelines regarding complete and proper clearances. ICAO should also encourage states to ensure [that the] controller's command of the English language is adequate to provide a safe environment;
- "That FAA ensure that the responsible parties review the navigational database protocols to establish a system in which ARINC 424 naming conventions match conventional charting practices;
- "That FAA require terrain contouring on arrival and approach charts;
- "That FAA require waypoint coordinates to be listed on approach charts;
- "That FAA and industry review current training standards/requirements to ensure an appropriate mix of automation skills and basic aviation abilities;
- "That FAA and equipment manufacturers make software changes to dramatically lower the tasking inherent with programming the FMC for a runway/approach change. Technology being used in new generation airplanes such as the Boeing 777 should be made available to operators of earlier generation FMS [flight management system]-equipped fleets; [and,]
- "That FAA and manufacturers ensure that vendors of navigational databases implement the ARINC 424 advisory dated Aug. 16, 1993, establishing 'terminal' and 'secondary' files for identically named navigational aids in the same geographical area."

Allied Pilots Association

In its comments regarding the investigation, the APA report said: "Areas of concern to APA are the relatively slow response times of the engines to accelerate to maximum power and the nondetermination of the input to power-lever movement. … APA requests that the acceleration rate of the engines, at conditions Flight 965 was operating under during the GPWS escape maneuver, be investigated to ensure the engines met design certification requirements."

Communications. The APA report commented on the workload encountered by the accident flight crew: "APA submits the following additional information giving evidence of crew task saturation during the arrival: There were 38 radio transmissions either received or made by the crew in the six-and-one-half minutes between the time they checked in with Cali Approach … and the receipt of the GPWS warning."

Navaid Selection. The APA report noted that the captain might have encountered a mechanical difficulty when selecting the Tulua VOR frequency: "When tuning the VOR to 117.7, it is quite possible that the captain did tune the radio to the desired frequency, but due to wear of the selector knob detents the frequency 'jumped' to 116.7. This is corrected by reselecting the correct frequency. Regardless of how the frequency of 116.7 became tuned in the captain's VOR, the resultant presentation on his navigational display would be the same and APA concurs with AA's assessment of the situation."

GPWS escape maneuver. The APA report commented on AA findings regarding the use of an angle-of-attack indicator for maximum performance during a GPWS escape maneuver: "APA fully supports AA's position on the inadequacy of the stick shaker in representing the angle-of-attack where the maximum coefficient of lift is attained. In order to extract the maximum available performance from our aircraft a functional, accurate angle-of-attack indicator coupled with a properly trained crew is required."

APA also commented on whether the accident flight crew might have been able to clear the terrain had the speedbrakes been retracted when the GPWS escape maneuver was initiated: "APA does not support any speculation on the capability of the aircraft to have cleared the ridge in another configuration. … There was no survey taken of the accident; all dimensions and heights are at best only rough estimates. Any conclusions drawn from [theoretical studies] should only be applied to a generic situation and not to the specific case of Flight 965."

Radar. APA commented on the accident flight crew's transition from a radar environment while en route to the nonradar environment of Cali Approach. "As the crew was transiting from Bogota Center's airspace into Cali Approach's airspace, there was never an advisory of 'radar contact lost.'

"It is quite possible that the [first officer] was unaware they were not in radar contact. Evidence of this fact is presented on the CVR transcript at time 2139:06 when in response to the captain's statement of 'Let's come to the right a little bit,' the [first officer] said, 'Yeah, he's wantin' to know where we're heading.' This indicates the [first officer] believed the controller was following their flight on radar. This theory is supported by the fact this was the [first officer's] first flight into Cali."

The APA made the following recommendations based on its participation in the investigation:

- "Pilots should receive more hands-on training in GPWS escape maneuvers while in unusual configurations. Training should include recoveries from nose-high/low-airspeed attitudes. It is also recommended that pilots receive more training in the support role the pilot not flying plays in the GPWS escape maneuver, e.g., 'coaching' the pilot flying with radio altimeter, airspeed and VSI [vertical speed indicator] readings, checking the aircraft configuration, etc. Training should also be expanded on GPWS maneuvers in high-density airspace and the possibility of false GPWS warnings;

- "The FAA should mandate [that] the GPWS escape maneuvers be a required item on annual pilot recurrent checks;

- "Pilots should receive more training in human factors effects of automation, especially concerning when it is proper to utilize different levels of automation to efficiently complete tasks at hand. More training should be conducted in the hazards associated with the resultant complacency that develops from flying automated aircraft;

- "If one pilot is flying in raw data, the other pilot should be in the MAP mode;

- "If the aircraft is flying in LNAV [lateral navigation], then one pilot should be in the MAP mode;

- "Pilots should receive more training in basic aerodynamics. [AA] has developed an excellent advanced aircraft-maneuvering program which incorporates aerodynamic-principle reviews and recovery from unusual attitudes. APA recommends that this type of program be established at all airlines;

- "Pilots should receive more training on maintaining altitude awareness in all phases of flight. Training should include the immediate consideration for climbing whenever navigational position is in doubt, especially when operating in the vicinity of mountainous terrain. Pilots should also receive additional training on operations in nonradar environments, specifically the need to ensure their own terrain clearance if operating off-airways when proceeding direct;

- "Pilots should receive more training in radar-altimeter awareness; e.g., a callout of 'radar altimeter alive' would alert the other pilot that the aircraft is approaching terrain;

- "Pilots should receive more training in FMS failures during line-oriented flight training (LOFT) scenarios. LOFT scenarios should also include placing the crew in situations that require exercising their situational awareness and decision-making skills;

- "Airlines should review division-specific qualifications for applicability to operations, specifically the establishment of 'division within a division' qualifications. For example, pilots who have been operating in the Atlantic/European operations area should not be allowed to operate in the South American operations area without having entered that area within a specific time frame or completing additional training;

- "Airlines should review crew resource management (CRM) training programs to ensure they address time and risk management, decision making and situational awareness prioritization;

- "Airlines should require that approach briefings include terrain awareness;

- "The FAA should review the certification requirements for engine spool-up time for aircraft situations such as [that encountered by] Flight 965; [and,]

- "The FAA should examine the benefits and feasibility of a throttle quadrant switch to automatically retract speedbrakes at high-throttle-lever positions and installation of a conspicuous 'speedbrake extended' advisory light that illuminates regardless of system altitude/configuration logic."

Boeing

A simulation of the accident flight's ground track and descent was conducted using data from the FMC recovered at the accident. Based on this simulation, Boeing provided a detailed analysis of the crew actions required to duplicate the descent. These actions were correlated with digital flight data recorder (DFDR) data from the accident aircraft. The following summarizes the Boeing analysis.

The Boeing 757 Flight Management System

The Boeing 757 flight management system (FMS) helps the pilot control the aircraft's lateral and vertical flight path. The FMS's primary functions are automatic navigation, optimization of in-flight performance and automatic fuel monitoring.

The flight management computer (FMC), manufactured by Honeywell Air Transport Systems, combines three elements: (1) flight plan information entered by the pilot, (2) information received from supporting systems and (3) information stored in its memory. From this information, the computer calculates the airplane's present position and the pitch, thrust and roll commands necessary to achieve an optimum flight profile.

The FMC sends commands to the autothrottles, to the autopilot and to the moving map display (see MAP mode, below). FMC commands are also sent to the flight director, which is used by the pilot to select the operating modes for the autothrottle and the autopilot.

The following definitions are paraphrased from the *Boeing 757 Operations Manual.*

Autothrottle — Automatically advances or retards power for climb, cruise, descent and approach in accordance with programmed or manual computer inputs.

CDI (course deviation indicator) — Shows actual track and its relationship to programmed course.

DIRECT TO — Selection of this function on the FMC highlights the active (destination) waypoint but removes all intervening waypoints from the FMC display.

EADI (electronic attitude-direction indicator) — Shows conventional airplane attitude indications (angle of bank, pitch); flight director commands; deviation from ILS localizer, glide slope and selected approach airspeed; and pitch limit.

EPR (engine pressure ratio) — The ratio of the turbine discharge total pressure to the turbine inlet total pressure. The EPR is used to set turbine engine power, much as manifold pressure is used to measure power output in a piston engine.

ESHI (electronic horizontal situation indicator) — Can be used in instrument landing system (ILS) or VOR mode. In VOR mode, the display shows a magnetic compass rose with CDI. In ILS mode, glide slope and azimuth to touchdown point are displayed.

FLCH (flight level change) — When selected, maintains existing airspeed and selected thrust for climb or idle thrust descent.

HDG SEL (heading select) — Allows the pilot to manually steer the aircraft by entering a magnetic compass heading into the computer.

LNAV (lateral navigation) — Generates computer steering commands to take the aircraft from its present position to the active waypoint. The LNAV mode is deactivated when HDG SEL is selected.

MAP mode — Displays flight information against a moving map of the actual area being traversed. Information displayed includes track, heading, wind, routes, distance to waypoint and estimated time of arrival. MAP mode is used for most phases of flight.

NAVAID button — Allows display of navigational fixes that are not on the programmed route.

VNAV (vertical navigation) — Accepts preprogrammed vertical flight profile for climb, descent and level-off. Sends commands to autothrottle system.

Vertical speed mode — Used by the pilot to select a computer-controlled constant rate of climb or descent. When vertical speed mode is selected, VNAV is deactivated.

VOR (Very high frequency omnidirectional radio range) — When VOR mode is selected, the pilot manually tunes the desired radio frequency.♦

Before starting their descent into Cali, the crew selected the instrument landing system (ILS) approach to Runway 1 on the FMC. The modifications made on the FMC suggested that they had briefed for the ILS approach. "No other arrival or departure procedures were selected for the remainder of the flight," the Boeing report said. "The ILS approach to Runway 1 and the associated missed approach to Rozo remained in the FMC and, with the appropriate map scale selected, were available for view on the EHSI [electronic horizontal situation indicator] MAP page for the remainder of the flight." (See "The Boeing 757 Flight Management System," above, for an explanation of terms.)

AA procedures require that, below 25,000 feet, "one pilot should monitor VOR raw data on the EHSI, while the other pilot may monitor the MAP display," the Boeing report said. "Later in the flight, the crew appeared to have problems locating the ULQ VOR; therefore, it is uncertain which VOR, if any, may have been selected for raw data."

When Cali Approach cleared the crew to the Cali VOR, the captain read back, "Cleared direct to Cali VOR." The captain then executed the DIRECT TO function on the FMC, and the ULQ VOR disappeared from view on the map display. "Had the crew wished to view the FMC-generated position of the ULQ VOR at this point, or any subsequent point, the NAVAID button could have been selected on the EHSI control panel and a cyan ULQ VOR symbol would have appeared on the EHSI MAP display," the Boeing report said.

When the flight was approximately abeam of the ULQ VOR, one of the crew called up the "R" list from the navigational database. The first entry on this list was for the Romeo NDB, located 244 kilometers (132 miles) northeast of the accident flight's position. One of the crew executed this entry, "which caused a curved dotted white line to be drawn on the MAP display," the Boeing report said. "Additionally, a scratch pad message 'insufficient fuel' and a northeasterly bearing to 'R' would have appeared … . This modification was executed, although crew coordination of this action was not apparent on the CVR."

The airplane then entered a left turn, and "it is uncertain whether either pilot recognized the aircraft had been commanded to turn left," the Boeing report said. "Indications that the airplane was in a left turn would have included the following: the EHSI MAP display (if selected) with a curved path leading away from the intended direction of flight; the EHSI VOR display, with the CDI [course deviation indicator] displaced to the right, indicating the airplane was left of the direct Cali VOR course; the EADI [electronic attitude-direction indicator] indicating approximately 16 degrees of bank; and all heading indicators moving to the right. ... The captain appeared to have problems interpreting the location of the ULQ VOR."

When the aircraft was at 13,500 feet and on a heading of approximately 110 degrees, the "heading select" mode was engaged, and the airplane rolled out of the left turn and began a turn to the right. "If an EHSI had been selected in the VOR mode, the displayed CDI would have shown the airplane heading approximately 90 degrees away from the original direct Cali VOR 195 course," the Boeing report said.

At this point, "ULQ was entered in the [FMC] and executed," the Boeing report said. "The first officer remarked to the captain about turning left to Tulua, and the airplane rolled out of the right turn and began a turn to the left … . The captain said, 'Let's press on.'

"After further discussion, the airplane began a 20-degree bank HDG SEL turn to the right. The actual heading selected … is unknown; however, based on the rollout initiated just prior to the GPWS warning, it can be inferred that it was approximately 230 degrees, which would have coincided with a heading toward Rozo."

One of the crew then entered "R" into the FMC. "This entry was not executed, so ULQ remained the FMC-active waypoint," the Boeing report said. "The effect of this action on the EHSI MAP would have been a dotted white line curving to the left toward 'R' for Romeo. A portion of the magenta line depicting the direct course to ULQ may have been visible, depending on the selected map size. Had the direct 'R' been executed, no turn towards 'R' would have occurred, since the airplane was still in HDG SEL … ."

The Boeing report said, "As the airplane started to roll out of a 20-degree bank HDG SEL right turn, the vertical speed mode of the autopilot was selected … . It is unknown why this action was taken. However, it resulted in the thrust levers moving slightly off the idle stops.

"Immediately thereafter, the GPWS terrain warning sounded. The crew initiated a prompt and aggressive terrain-avoidance maneuver: turning off the autopilot while pushing the thrust levers full-forward, and rapidly increasing pitch attitude.

"The crew left the autothrottle engaged and the speedbrakes deployed full-up during the maneuver. DFDR data [indicate] that the engine parameters increased on the maximum acceleration schedule, consistent with the thrust levers being manually advanced at the beginning of the escape maneuver; however, the engines had insufficient time to reach full thrust prior to impact."

As a result of its participation in the investigation, Boeing made the following additional recommendations:

- "Manufacturers, airlines and regulatory agencies should develop a process to identify and rectify incorrect navaid database and ground-position information to allow full use of FMS map displays within the certified limitations of the approved airplane flight manual; [and,]

- "ICAO and regulatory authorities should review controller's handbooks and training to [ensure] a standardized worldwide definition of the terms 'to' and 'direct to' consistent with the functionality of FMC-equipped airplanes."♦

U.S. 1997 Rotorcraft Accident Rate Was Lowest in Seven Years

U.S. air-taxi accident rate also declined slightly.

FSF Editorial Staff

The U.S. rotorcraft accident rate was 7.84 accidents per 100,000 flight hours in 1997, lower than in any of the six previous years, according to data from the U.S. Federal Aviation Administration (FAA). There were fewer rotorcraft accidents — 166 — than in any year in the 1991–1997 period except 1995, when there were 162.

During the 1991–1997 period, the rotorcraft accident rate ranged as high as 10.62 accidents per 100,000 flight hours in 1994 (Figure 1 and Table 1), when the number of accidents also peaked at 207.

Incidents are another system-safety indicator. The rotorcraft incident rate declined to 3.26 per 100,000 flight hours, also the lowest of any year in the 1991–1997 period (Table 2). There were 69 rotorcraft incidents in 1997, a decline from 73 in 1996 and 125 in 1995.

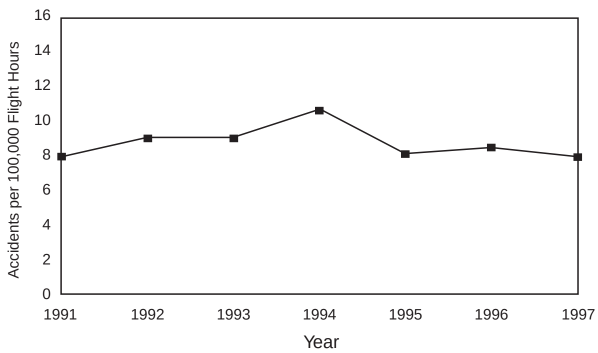
U.S. air-taxi accidents also declined in 1997 compared with 1996. [Air taxis are defined by the FAA as on-demand air carrier operations conducted under U.S. Federal Aviation Regulations (FARs) Part 135 for compensation or hire that include: (1) nonscheduled passenger-carrying operations conducted with (i) airplanes, including turbojet-powered airplanes, having a passenger-seat configuration of 30 seats or fewer, excluding each crewmember seat, and a payload capacity of 7,500 pounds or less, or (ii) rotorcraft; (2) scheduled passenger-carrying operations conducted with one of the following types of aircraft with a frequency of operations of less than five round trips per week on at least one route between two or more points according to the published flight schedules: (i) airplanes, other than turbojet-powered airplanes, having a maximum passenger-seat configuration of nine seats or less, excluding each crewmember seat, and a maximum payload capacity of 7,500 pounds or less; or (ii) rotorcraft; or (3) all-cargo operations conducted with (i) airplanes having a payload capacity of 7,500 pounds or less, or (ii) rotorcraft. The statistics presented here do not include commuter air carriers — scheduled passenger operations conducted under Part 135 that, effective March 20, 1997, are defined by the FAA as operations using one of the following types of aircraft with a frequency of operations of at least five round trips per week on at least one route between two or more points according to the published flight schedules: (i) airplanes, other than turbojet-powered airplanes, having a maximum passenger-seat configuration of nine seats or less, excluding each crewmember seat, and a maximum payload capacity of 7,500 pounds or less; or (ii) rotorcraft.]

The 1997 air-taxi-accident rate was 4.14 per 100,000 flight hours, the lowest since 1993 (Figure 2 and Table 3). The air-taxi-accident rate in the 1991–1997 period ranged from a low of 3.80 in 1992 to 4.47 in 1994. There were 82 air-taxi accidents in 1997, compared with 89 in 1996.

U.S. air-taxi incidents occurred at a rate of 7.42 per 100,000 flight hours, compared with 8.20 per 100,000 flight hours in 1996 and 11.55 per 100,000 flight hours in 1995 (Table 4). There were 147 incidents in 1997, compared with 164 in 1996 and 201 in 1995.

The FAA cautioned that both rotorcraft flight hours and air-taxi flight hours are imprecise values. Changes in rates and numbers of accidents or incidents from one year to the next may not be statistically significant because of random variation.

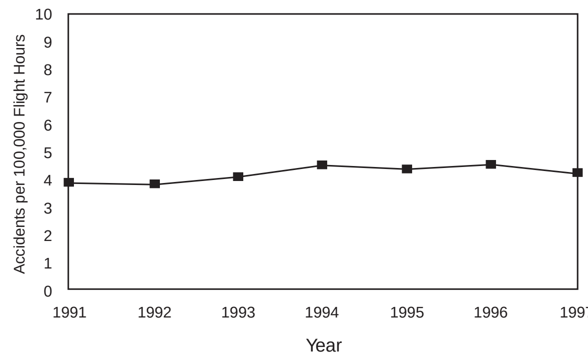
All U.S. Rotorcraft Accident Rates



Source: U.S. Federal Aviation Administration

Figure 1

All U.S. Air-taxi Accident Rates



Source: U.S. Federal Aviation Administration

Figure 2

Table 1
All U.S. Rotorcraft Accidents

Year	No. of Accidents	No. of Flight Hours	Accident Rate (per 100,000 flight hours)
1991	190	2,356,172	8.06
1992	194	2,136,495	9.08
1993	175	1,929,345	9.07
1994	207	1,949,558	10.62
1995	162	2,011,915	8.05
1996	178	2,093,405	8.50
1997	166	2,116,859	7.84

Source: U.S. Federal Aviation Administration

Table 2
All U.S. Rotorcraft Incidents

Year	No. of Accidents	No. of Flight Hours	Accident Rate (per 100,000 flight hours)
1991	103	2,356,172	4.37
1992	86	2,136,495	4.03
1993	99	1,929,345	5.13
1994	80	1,949,558	4.10
1995	125	2,011,915	6.21
1996	73	2,093,405	3.49
1997	69	2,116,859	3.26

Source: U.S. Federal Aviation Administration

Table 3
All U.S. Air-taxi Accidents

Year	No. of Accidents	No. of Flight Hours	Accident Rate (per 100,000 flight hours)
1991	87	2,241,000	3.88
1992	76	2,000,000	3.80
1993	69	1,700,000	4.06
1994	85	1,900,000	4.47
1995	75	1,740,000	4.31
1996	89	2,000,000	4.45
1997	82	1,980,000	4.14

Source: U.S. Federal Aviation Administration

Table 4
All U.S. Air-taxi Incidents

Year	No. of Accidents	No. of Flight Hours	Accident Rate (per 100,000 flight hours)
1991	197	2,241,000	8.79
1992	148	2,000,000	7.40
1993	150	1,700,000	8.82
1994	183	1,900,000	9.63
1995	201	1,740,000	11.55
1996	164	2,000,000	8.20
1997	147	1,980,000	7.42

Source: U.S. Federal Aviation Administration

Publications Received at FSF Jerry Lederer Aviation Safety Library

The U.S. General Accounting Office Reports Lag in Implementation of Airline Security Measures

National Business Aviation Association marked its 50th anniversary by publishing comprehensive history of business flying.

FSF Library Staff

Reports

Aviation Security: Implementation of Recommendations Is Under Way, but Completion Will Take Several Years. U.S. General Accounting Office (GAO), Report to Congressional Requesters, April 1998. Report no. GAO/RCED-98-102. 59 pp. Tables, figures, appendixes. Available through GAO.*

Concern about domestic aviation security in the United States has grown with the increasing threat of terrorist activities. Thirty-one recommendations on aviation security made by the White House Commission on Aviation Safety and Security are now being implemented by the U.S. Federal Aviation Administration (FAA), other federal agencies and the aviation industry. Implementation of the White House Commission recommendations is crucial to strengthening the security of domestic aviation in the United States.

This report addresses three questions: How do the federal agencies responsible for the implementation of aviation security recommendations track, monitor and coordinate their activities? What progress has the FAA made in implementing three of the White House Commission's aviation security recommendations that were scheduled to be completed in fiscal year 1997, and has the agency resolved all implementation issues? What progress has the FAA made in implementing five recommendations made by the White House Commission and mandated by Congress in 1996, and what major issues remain before full implementation?

The report finds that the FAA and eight other federal agencies are individually responsible for implementation of White House Commission recommendations and tracking their progress. Without oversight or coordination from the U.S. National Security Council or another federal agency, any issues that arise between agencies may go unresolved.

The report also reviews three recommendations that the FAA planned to complete in fiscal year 1997. Only one, giving properly authorized air carrier and airport-security personnel access to classified information that they need to know, has been implemented on schedule.

The second recommendation, establishing procedures for identifying passengers before boarding aircraft, must incorporate further information from ongoing recommendations before it can be fully implemented.

The third recommendation, to establish a partnership among airport and air carrier officials and law-enforcement agencies to implement security enhancements, cannot be expanded until the issue of self-disclosure of security violations has been resolved by the FAA. Five other Commission recommendations have been delayed because they involve new technologies, and in some cases, require the FAA to issue regulations. [Adapted from Introduction and Results in Brief.]

Air Traffic Control: Evolution and Status of FAA's Automation Program. Statement of Gerald L. Dillingham, Associate Director, Transportation Issues, Resources, Community, and Economic Development Division, U.S. General Accounting Office (GAO), before the Subcommittee on Aviation, Committee on Commerce, Science and Transportation, U.S. Senate, March 5, 1998. Report no. GAO/T-RCED-98-85. 14 pp. Appendixes. Available through GAO.*

This testimony discusses the air traffic control (ATC) automation program of the U.S. Federal Aviation Administration (FAA). Automation and other functional areas such as communications, navigation and surveillance are the main elements of the FAA's overall plan to modernize the ATC system.

The automation program, which began in the early 1980s, concerns the acquisition of modern workstations and computers that process radar and flight data for controllers' use. In 1994, FAA restructured its automation program because of cost, scheduling and technical problems. At the time, the centerpiece of the program was the Advanced Automation System (AAS) project, which was divided into five separate segments. Between 1983 and the 1994 restructuring, the estimated cost to develop AAS has risen from US$2.5 billion to as much as $7.6 billion, and the original completion date of 1996 has been revised to be as late as 2003.

Under the restructured program, the FAA will acquire major components for two segments of AAS: the Display-System Replacement (DSR), and Standard-Terminal-Automation Replacement System (STARS). Other major acquisitions will also be necessary to provide the capabilities promised under AAS.

The testimony focuses on three areas: how the automation program has evolved from the initial program to the present one; to what extent the FAA has had to implement costly interim projects to keep older equipment operating; and whether ongoing acquisitions are meeting cost and schedule expectations.

Among the findings: Despite restructuring, the FAA still intends to replace aging mainframe computer hardware during fiscal years 1998 and 1999, at a cost of about US$160 million; four interim projects have been added by the FAA to sustain current automated equipment used to control air traffic at lower altitudes near airports, at a cost of about US$655 million; and the DSR is currently within budget and on schedule, but the STARS is facing a schedule delay of at least six months because of additional software development and testing. [Adapted from Introduction.]

Global Fatal Accident Review: 1980-96. U.K. Civil Aviation Authority, London. CAP 681. March 1998. 41pp. Figures, tables, references, appendix. Available through Westward Digital Limited.**

This review summarizes an analysis of 621 fatal accidents worldwide, 1980–1996, involving jet and turboprop aircraft weighing more than 5,700 kg (12,566 lb.). These accidents caused 16,849 fatalities. The study highlights the most important causes and circumstantial factors of these fatal accidents to focus attention on necessary changes in training or operating procedures, and to identify areas for possible regulatory action. During 1980–1996, North American and European operators achieved the lowest fatal-accident rates, with 0.37 and 0.52 fatal accidents per million flights, respectively. Half of the 621 fatal accidents occurred during the approach and landing phases of flight. The most frequently identified causal factor (41 percent of all fatal accidents) was "lack of positional awareness in air." The most frequently identified consequences were "collision with terrain/water/obstacle," "controlled flight into terrain (CFIT)," and "loss of control in flight." The fatal-accident rate for freight, ferry and positioning flights was estimated to be eight times greater than the fatal-accident rate for passenger flights. [Adapted from Executive Summary.]

TSB Statistical Summary: Aviation Occurrences: 1997. Transportation Safety Board of Canada. 12pp. Tables. Available through Transportation Safety Board of Canada.***

This publication contains a summary of selected statistics on aviation occurrences in Canada in 1997. During that year, 425 accidents were reported to the Transportation Safety Board of Canada (TSB), 353 of which involved Canadian aircraft. The accident rate is estimated to have risen from 8.8 accidents per 100,000 flight hours in 1996, to 9.1 accidents per 100,000 flight hours in 1997, based on indications of a small increase in flight activity. The 353 accidents involved 292 aircraft and 56 helicopters. There were 36 fatal accidents in 1997, a decrease of 16 percent from 1996. The statistics presented in this annual summary reflect current figures as of February 11, 1998.

Books

NBAA's Tribute to Business Aviation. Searles, Robert A. with Parke, Robert B. Washington, D.C., United States: National Business Aviation Association (NBAA) Inc., 1997. 168 pp.

Containing numerous photographs, *NBAA's Tribute to Business Aviation* chronicles the development of business aviation in the United States from its humble beginnings to the sophisticated supersonic business jets planned for the future. The eight chapters take the reader to the dawn of business flying in the 1920s, through the Great Depression, to the increase in popularity after World War II and the advances in technology of more recent decades. It is apparent how the equipment used for business flying has evolved from single-engine, piston-powered aircraft to converted World War II military aircraft and modern turboprops and jets. But most of all, this tribute documents how business aviation contributes to the unprecedented mobility of American business executives and makes business aviation an important element of the U.S. economy and air-transportation system.

This oversized, limited-edition book is published as part of the 50th-anniversary celebration of the NBAA. The association is based in Washington, D.C., and represents the nearly 5,000 companies that own, operate or support aircraft used for business transportation. Includes an index. [Adapted from Introduction.]

World Directory of Airliner Crashes: A Comprehensive Record of More than 10,000 Passenger Aircraft Accidents. Denham, Terry. Sparkford, Nr Yeovil, Somerset, England: Haynes Publishing, 1996. 320 pp.

Through 27 years of research, author Terry Denham has assembled a compilation of aviation-accident information gathered from thousands of sources worldwide. Here readers will find details of nearly 11,000 aviation accidents, the famous as well as the forgotten — accidents resulting from human error, mechanical failure, weather, sabotage and military action.

The criteria for inclusion in the directory were expanded to include most accidents to transport-category aircraft capable of carrying eight or more passengers, regardless of whether operated by an airline, a corporation or an individual. The one common element is that the accidents all resulted in the write-off of the aircraft. The accident data in the directory are arranged by decade for the most part, except for the first historical period, 1906–1939, and the latest, 1990–1995. An authoritative single-volume reference work for the aviation enthusiast and serious professional researcher alike.

Includes several appendices: (A) Crashes with No Known Date; (B) Crashes by Aircraft Type; (C) Crashes by Operator; (D) Civil Types in Military Use; (E) Nationality Prefix Index; and Late Entries. [Adapted from Introduction.]♦

Sources

* U.S. General Accounting Office (GAO)
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Updated Regulations and Reference Materials

U.S. Federal Aviation Administration (FAA) Advisory Circulars (ACs)

AC No.	Date	Title
90-91B	April 15, 1998	*National Route Program.* (Cancels AC 90-91A, *National Route Program,* dated May 13, 1996.)

International Reference Updates

Aeronautical Information Publication (A.I.P.) Canada

Amendment No.	Date	
3/98	16 July 1998	Updates the General, Meteorology, Rules of the Air and Air Traffic Services, Facilitation, Aeronautical Charts and Publications, and Airmanship sections of the A.I.P.

Airclaims

Update No.	Date	
108	12 June 1998	Updates "*Major Loss Record.*" Worldwide aircraft accident summaries.
Supplement 111	June 1998	Updates "*World Aircraft Accident Summary (WAAS).*" The introduction, index and 1997 sections have also been completely revised.

Joint Aviation Authorities (JAA)

Date	
1 June 1998	Revision to JAA Administrative and Guidance Material — Section One — General Guidance & Reference Material.
1 June 1998	Revision to JAA Administrative and Guidance Material — Section Three — Certification.
1 July 1998	Revision to JAA Administrative and Guidance Material — Section One — General Guidance & Reference Material.

Accident/Incident Briefs

Bird Ingestion Causes A320 Engine Failure And Fire during Takeoff

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

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FSF Editorial Staff

Turbojet Engine Bursts into Flames After Ingesting Large Bird

Airbus A320. Minor damage. No injuries.

About 400 feet above ground level during the aircraft's takeoff from an airport in the United States, one of the engines ingested a large bird. The engine failed and burst into flames. Passengers reported hearing a boom, followed by a sound similar to that made by a kitchen blender. The engine fire was extinguished, and the aircraft circled over the ocean for about 30 minutes, dumping fuel to attain maximum landing weight. The aircraft then landed at the departure airport, where passengers made an orderly exit.

Use of Incorrect Approach Chart Leads to Premature Descent

Boeing 747-200. No damage. No injuries.

The flight crew briefed for an instrument-landing system (ILS) approach to Runway 19R at an airport in Africa. The crew received no glideslope signal after they turned the aircraft onto the final approach course. The crew had the ground and the airport lights in sight. The captain asked the first officer to call out the published VOR/DME (very high frequency omnidirectional radio range/distance-measuring equipment) approach heights as they proceeded with a visual approach. The first officer selected the appropriate VOR but read the heights published on the ILS approach chart. The VOR and ILS heights apparently were based on distances obtained from different DME sources. The aircraft descended to 500 feet, six miles from the runway (1,900 feet below the correct descent profile). The captain initiated a go-around. The aircraft was climbing through 1,200 feet when the crew gained visual contact with the runway. The aircraft then was landed without further incident.

DC-10 Evacuated after Engine Fire Occurs while Taxiing

McDonnell Douglas DC-10. Minor damage. Two minor injuries.

The aircraft was taxiing to the runway for takeoff at an airport in England when fuel was seen leaking from one of the engines. The leak was reported to the flight crew, who began to return the aircraft to the gate. Flames then were seen coming from the back of the aircraft as it taxied toward the airport terminal. The captain ordered an evacuation, and all 249 occupants exited through emergency chutes. Two occupants sustained minor injuries while sliding down the chutes. Firefighters quickly extinguished the flames.

Food Poisoning Suspected Of Incapacitating Pilot

Boeing 737. No damage. No injuries.

The aircraft was in flight when the first officer became ill with suspected food poisoning and could not remain at his station. The captain summoned to the cockpit a Boeing 727 flight engineer who was among the passengers on the flight. The captain thoroughly briefed the flight engineer, who then occupied the first officer's station, operated the radios and read the checklists.

Aircraft Rolls off Runway After Brakes Fail on Landing

Airbus A320. Substantial damage. Fifteen injuries.

The A320's brakes failed after the aircraft touched down on the runway at an airport in England. The aircraft rolled off the end of the runway and skidded on grass for 600 feet (182 meters) before coming to a halt. The A320's nose landing gear and the cowling on one engine were damaged. The 180 passengers used emergency chutes to evacuate the aircraft. Fifteen passengers sustained minor injuries. One passenger suffered an attack of asthma during the evacuation and was hospitalized. None of the seven crewmembers was injured.

Air Taxi Commuter

Aircraft Ditched in Ocean After Losing Power

Piper Chieftain. Aircraft destroyed. One fatality, one minor injury.

The twin-engine aircraft was descending from cruise altitude over the ocean to land at a major metropolitan airport in the United States when the pilot reported that the left engine had lost power and that the engine cowling was open. The flight crew performed the engine-out emergency procedures but were unable to arrest a descent rate of 300 feet to 500 feet per minute. The captain instructed the four passengers to put on their life vests and then informed air traffic control that he was going to ditch the aircraft. All of the occupants exited through the cockpit emergency door after the aircraft came to rest in the water. They were rescued by a helicopter and a police boat 30 minutes later. The aircraft sank in about 85 feet of water. One passenger suffered cardiac arrest and eventually died, and the first officer sustained minor injuries. The other four occupants escaped injury.

Aircraft Strikes Snowbank On Runway Threshold

Britten-Norman Islander. Substantial damage. No injuries.

The twin-engine aircraft was landing at an airport in Canada during a charter flight when it struck the top of a four-foot snowbank near the runway threshold lights. The snowbank had been left on the runway earlier that day by a snow-clearing crew. The pilot reported that the snowbank was not visible from the air. The pilot, the sole occupant, was not injured. He said that he saw no aircraft damage after landing. Several days later, however, the pilot had difficulty extending the aircraft's flaps. Examination revealed structural damage where an engine mount is attached to a landing-gear leg. After the accident, the airport changed its snow-clearing practices to deposit snow at the end of the runway clearway, rather than at the threshold.

Float-equipped Aircraft Strikes Shoreline During Aborted Takeoff from Lake

De Havilland Beaver. Substantial damage. No injuries.

A snow shower began after the float-equipped single-engine airplane landed on a lake to pick up two hunters for an air-taxi flight. The snow stopped falling as the pilot loaded the aircraft. The pilot said that because he easily was able to brush snow off the tail of the aircraft, he did not remove snow from the other parts of the aircraft before takeoff. The aircraft lifted off the surface of the lake but would not climb above five feet of altitude. The pilot aborted the takeoff but had insufficient room in which to stop the aircraft. The Beaver was substantially damaged when it crashed on the shoreline. The pilot was not injured.

Inspection Required After Unusually Hard Landing

Britten-Norman Islander. Substantial damage. No injuries.

The twin-turboprop transport aircraft made a hard landing on what was described as a rugged runway on a South Pacific island. The accident occurred in daylight. There were nine people aboard the aircraft, including the pilot. A spokesman for the airline said that the aircraft would remain on the island until engineers had a chance to assess the damage to the landing gear and to evaluate the aircraft's airworthiness.

Corporate Executive

Jet Hits Deer During Night Landing

Cessna Citation III. Substantial damage. No injuries.

Two seconds after touching down and decelerating from approximately 120 knots on the runway at an airport in England, the aircraft struck a small deer. The left main landing gear, left inboard flap and left landing light were substantially damaged. The two pilots and eight passengers were not injured. The airport controller had inspected the runway and taxiways prior to the 0730 accident. The deer is believed to have jumped over a four-foot airport boundary fence.

Twin Hydroplanes on Wet Runway, Comes to Rest on Public Road

C-421C. Substantial damage. No injuries.

The pilot said that after touching down at a normal landing airspeed of 90 knots and applying the brakes, the aircraft began to slide down the runway. The runway was wet and had 2,310 feet (700 meters) of hard surface available for landing. The pilot said that he determined the twin-engine aircraft was hydroplaning and would not stop on the runway remaining, so he raised the flaps and shut off the engines. The aircraft was traveling about 19 knots when it ran off the end of the runway and came to a rest on a public road. The tail section and the flap, aileron and landing gear on the right wing were substantially damaged. None of the three occupants was injured.

Quartering Tailwind Causes Trouble for Twin Beech

Beech D18S. Substantial damage. One serious injury, two minor injuries.

The twin-engine Beech was landing with a 20-knot, quartering tailwind at a mountain airport. A witness said that the landing appeared to be normal until the right wing suddenly rose and the left wing scraped the runway. The airplane then spun around and came to rest in the median between the runway and the taxiway. The pilot was seriously injured. The copilot and a passenger sustained minor injuries.

King Air Strikes Ground During Instrument Takeoff in Fog

Beech E90 King Air. Aircraft destroyed. Two fatalities.

The twin-engine aircraft was making an early-morning instrument departure in weather conditions including a 100-foot overcast and 3.5 miles visibility in fog. Shortly after takeoff, the pilot asked air traffic control (ATC), “Can you tell if I’m in a turn? I have a problem here.” The controller advised that the airplane was heading west, then south, then east. Witnesses heard the airplane circling overhead before it descended out of control. The pilot and his passenger were killed.

Other General Aviation

Forced Landing Occurs As Pilot Seeks Alternate Refueling Site

Cessna 152. Aircraft destroyed. Two minor injuries.

The single-engine aircraft was on a dual, cross-country instruction flight at night. The flight instructor and student pilot landed at their intended refueling site but found that the refueling facility was closed for the night. They took off and were proceeding to another refueling site when the engine lost power. The aircraft was destroyed during the subsequent forced landing, and the two occupants sustained minor injuries. Preliminary investigation disclosed no fuel remaining in the aircraft’s tanks.

Jet Blast from Boeing 747 Overturns Cessna 172 Taxiing Behind

Cessna 172K. Substantial damage. No injuries.

The light single-engine airplane taxied behind a Boeing 747 four-engine jet airplane that was stopped on an intersecting taxiway with engines operating. The crew of the B-747 was awaiting clearance onto the deicing pad at the Canadian airport. The Cessna 172 was tipped onto the right wing tip and propeller by jet blast from the B-747. The operator of the Cessna reported that the right wing-tip fairing was broken, the lower wing spar was bent, the wing skin was damaged and the leading edges of the propeller-blade tips were nicked.

Aircraft Strikes Hangar on Landing At Unlighted Airport at Night

Beech Travel Air. Substantial damage. No injuries.

The pilot was unable to activate the airport's radio-controlled lighting system but elected to proceed with the night landing. The aircraft touched down between the runway and a parallel taxiway, struck a mound of earth and then crashed into a hangar. Aircraft damage was substantial, but the three occupants were not injured.

Aircraft Strikes Mountain Ridge After Entering Rain

Piper Lance. Aircraft destroyed. Four fatalities.

The pilot, who was not instrument-rated, received a weather briefing in the morning but did not update the information before taking off late in the afternoon for a VFR (visual flight rules) flight in the United States. Visual meteorological conditions existed on departure, but localized adverse weather conditions, including low ceilings and snow, existed along the route of flight. Shortly after departure, the pilot told ATC that he was descending because the ceilings were getting lower. ATC told the pilot that the single-engine aircraft was traveling toward areas of precipitation. The pilot acknowledged the information. ATC then terminated radar advisory services. About three minutes later, the aircraft struck on a mountain ridge at an altitude of about 6,200 feet. All four occupants were killed.

Pilot Did Not Consider Go-around Before Aircraft Ran Off Runway

Beagle A.61. Substantial damage. No injuries.

The aircraft was involved in a glider-towing operation. The pilot completed one tow flight to 3,000 feet and descended to land on the 2,100-foot (636-meter), grass runway. The landing approach was made in the direction of the setting sun. The pilot said that he was distracted by a glider parked on the left side of the touchdown zone, and the distraction caused him to delay reducing power to idle for about three seconds. The aircraft touched down farther down the runway than normal. The pilot said that he was not aware that the departure end of the runway was near when he applied the Beagle's toe brakes. He said that the option of increasing power and going around did not occur to him because he subconsciously reverted to his previous 29 years of experience in landing gliders, in which the option of a go-around was not available. The aircraft ran off the end of the runway at about 15 knots and then flipped over when the wheels sank into softer ground. The pilot was not injured.

Rotorcraft

Bell 212 Creates Whiteout Conditions While Landing on Snow-covered Lake

Bell 212. Substantial damage. Injuries unknown.

The helicopter made a fairly steep and slow approach to a featureless, snow-covered, frozen lake in Canada to pick up passengers. The helicopter was drifting sideways when the skids touched the ice. The helicopter began to roll, and the main rotor struck the ice. The Bell 212 then rolled over. Injuries to the pilot, alone aboard the aircraft, were not reported. The sky was obscured, and visibility was about one mile. The report said that whiteout conditions and loss of visual cues were probable causes of the accident.

Forced Landing Follows Misfueling of Hughes 269

Hughes 269A. Substantial damage. No injuries.

The helicopter lost engine power shortly after taking off for an instructional flight in the United States. During the forced landing, the right landing skid separated, and the helicopter cartwheeled onto its nose. The flight instructor and his student were not injured. The helicopter had been refueled before it took off. Examination revealed that the fuel tanks had been filled with Jet A fuel, instead of 100LL aviation gasoline.

Fuel Contamination Causes Engine Failure on Takeoff

McDonnell Douglas 369D. Substantial damage. No injuries.

The helicopter was on initial climb after takeoff when the engine lost power. The pilot attempted to make an emergency landing in a field. The helicopter landed hard, and the main rotor blades severed the tail boom. The pilot was not hurt. Investigation revealed that the helicopter's fuel system was contaminated and that the engine fuel nozzles were partially blocked.♦

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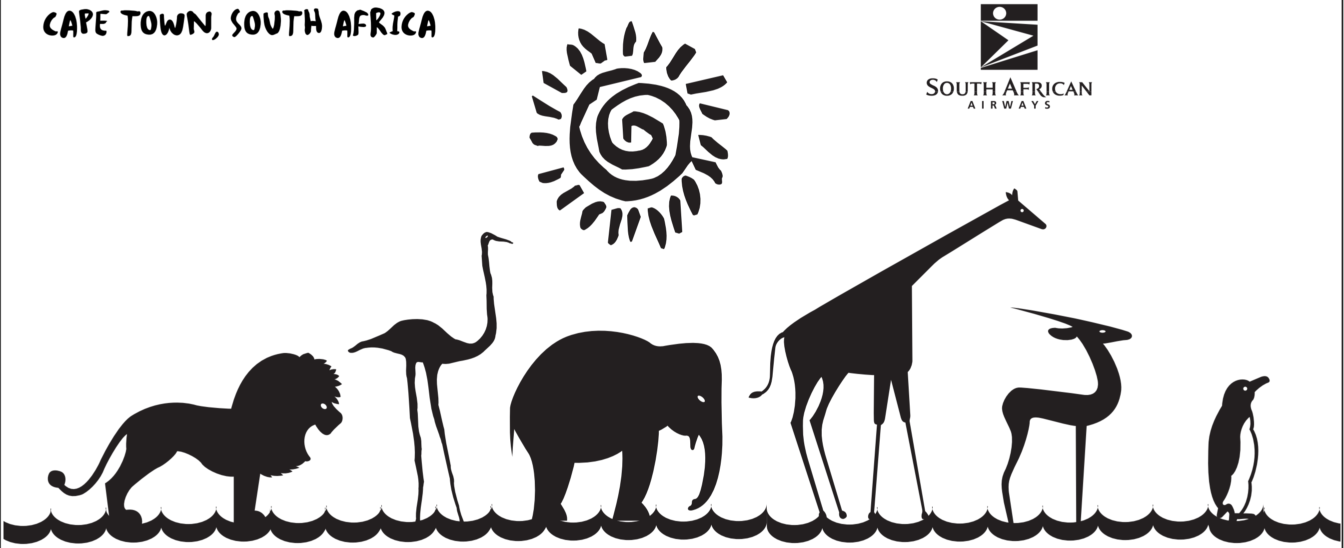

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