Log# 2612

# National Transportation Safety Board

Washington, D.C. 20594

**Safety Recommendation**

Date: October 16, 1996

In reply refer to: A-96-90 through -106

Honorable David R. Hinson
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On December 20, 1995, about 2142 eastern standard time, American Airlines (AAL) flight 965, a regularly scheduled passenger flight from Miami, Florida, to Cali, Colombia, struck trees and then crashed into the side of a mountain near Buga, Colombia, in night, visual meteorological conditions, while descending into the Cali area. The airplane crashed 33 miles northeast of the Cali (CLO) very high frequency omnidirectional radio range (VOR) navigation aid. The airplane was destroyed, and all but four of the 163 passengers and crew on board were killed.

The investigation was conducted by the Aeronautica Civil of the Government of Colombia, with assistance from the National Transportation Safety Board, in accordance with the provisions of Annex 13 to the Convention on International Civil Aviation. Assistance was also provided by the Federal Aviation Administration (FAA), AAL, the Allied Pilots Association, the Boeing Commercial Airplane Group, and Rolls-Royce, Inc., (the engine manufacturer). The Safety Board received a copy of Aeronautica Civil's report of the investigation on September 27, 1996.

Information about the circumstances of this accident was obtained from a variety of sources: the airplane's cockpit voice recorder (CVR), digital flight data recorder (DFDR), and flight management system (FMS) computer; and recorded air traffic control (ATC) communications. Although the information obtained was considerable, and the DFDR provided substantial data, such as the engagement status and mode selection of the airplane's automatic flight control system, other pertinent information was not recorded, including pilot-selected navigation aids; pilot inputs into the control-display units; selected mode specific parameter values, such as heading, airspeed, altitude, and vertical velocity; and selected electronic horizontal situation indicator (EHSI) formats, such as maps, scales, and radio facilities selected to be displayed. Such data would have considerably enhanced the quality and quantity of information regarding crew actions preceding the accident. The Safety Board intends to address the issue of flight recorder data more fully in future correspondence with the FAA.

The data that were obtained reveal, in part, that the flight was uneventful until the airplane entered the Cali airspace. The first officer was the flying pilot, and the captain, as the non-flying pilot, was performing all communications with ATC. Before reaching BUTAL, a fix on the airway "Upper Green (UG) 438," the airplane was cleared to the TULUA VOR. At 2126:42, while descending from flight level (FL) 370[1] to FL 240, the captain contacted AAL operations at Cali, estimated the flight's arrival time to be in 25 minutes, and requested weather information. AAL operations reported that the weather was good, the temperature was 72°, the altimeter was at 29.98 inches of mercury, and runway 01 would likely be the active runway.

At 2134:40, when flight 965 was about 63 miles north of CLO and descending to FL 200, the captain contacted Cali approach control.[2] At 2134:59, the Cali controller told flight 965 that it was "cleared to Cali VOR," and then added, "no delay expect for approach report [crossing] TULUA." The captain responded, "OK understood. Cleared direct to Cali VOR. Uh, report TULUA." The controller responded, "Affirmative." During the next 3 minutes, the flight received descent clearances and was offered the approach to runway 19; after a brief discussion, the flightcrew accepted the controller's offer.

At 2137:43, flight 965 passed TULUA on a heading of 193°, in a descent from FL 180, at an airspeed of 288 knots. The throttles were at flight idle and the speedbrakes were extended about ½, when the airplane began a left, descending turn. At 2137:46, the controller said, "report TULUA and eeh, twenty one miles, ah, five thousand feet." During the turn, the captain and first officer discussed their uncertainty regarding their location with respect to TULUA and the airport. The airplane continued to descend, and the speedbrakes were further extended to about ¾ and then full. Ninety-eight seconds after the turn began, the airplane stopped turning left at a heading of 101°, and the first officer initiated a right, descending turn to the southwest.

At 2141:05, about 104 seconds after the right turn began, the airplane was descending through 8,839 feet msl, its airspeed was 240 knots indicated airspeed (KIAS), its descent rate was 1,400 to 1,500 feet per minute, its throttles were at idle, and its speedbrakes were fully extended. Eleven seconds later, while the airplane was passing through 8,571 feet msl, the ground proximity warning system (GPWS) began issuing aural warnings of "TERRAIN" and "PULL-UP." These warnings continued for 12 seconds, until 2141:28, the end of the recorded data.

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[1]Altitude expressed in hundreds of feet mean sea level (msl).

[2]Approach control radar coverage was not available for ATC in the Cali area.

Within 2 seconds after the initial GPWS alert, thrust[3] and airplane pitch attitude both began increasing. The pitch increase continued for 3 seconds to an attitude 20.6° nose up, at which point the stick-shaker warning activated. The airplane climbed to 8,987 feet msl, a net gain of 436 feet from its lowest recorded altitude of 8,551 feet msl before striking trees at the summit of a mountain ridge. The final recorded airspeed was 187 KIAS, the pitch attitude was 27.9°, the rate of climb was about 100 feet per second, and the resultant climb angle was about 15°. The speedbrakes, which had been extended earlier during the descent, remained extended during the entire sequence. Evidence indicates that the flightpath of the airplane through the trees was about 300 feet long and that the tail of the airplane struck the trees first. The absence of gouging in the soil indicates that the airplane cleared the ridge without ground contact. However, the airplane sustained catastrophic damage as a result of the tree strikes and crashed on the other side of the mountain.

**American Airlines Corrective Actions**

This accident occurred 38 days after a nonfatal accident involving AAL flight 1572, an MD-83, which was substantially damaged when it flew through trees during a non-precision approach to runway 15 at Bradley International Airport, Connecticut, on November 12, 1995. Because this and the Cali accident both involved controlled flight into terrain (CFIT), the Safety Board became concerned about the need for urgent safety recommendations to prevent similar accidents. However, immediate actions by the FAA and AAL mitigated the need for recommendations at that time.

AAL, with the cooperation of the FAA, formed a Safety Assessment Program to examine critical phases of its operations. When the examination is complete, AAL will issue a final report by January 1997, with quarterly progress meetings and a 6-month interim report.

The airline briefed the Safety Board and the FAA at the 6th month or midpoint of its Safety Assessment Program and informed them that the program is proceeding on schedule. The Safety Board appreciates these efforts, will follow the progress of the program, and looks forward to receiving the final report.

AAL also established a CFIT Task Force and a Non-Precision Approach Working Group, and added specific guidance on pilot response to CFIT scenarios into its Advanced Aircraft Maneuvering Program. All simulators now have specific terrain profiles that will cause GPWS terrain warnings, so that the pilots will practice executing terrain escape maneuvers by extracting maximum aircraft performance in recovery.

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[3]The DFDR records the commanded EPR values once every 4 seconds but does not record power lever positions At 2141:18, the commanded EPR was 1 721, and at 2141:26 the final commanded EPR was the maximum available, 1 756 The final EPR value of 1 348 was consistent with the schedule for engine spool-up toward the commanded EPR.

**GPWS Escape Maneuver**

Results of an initial study the Safety Board conducted of the performance of flight 965 following the GPWS warning indicate that had the speedbrakes been retracted 1 second after initiation of the escape maneuver, the airplane would have been able to climb 150 feet above the initial impact point, possibly clearing the mountain. In addition, had the speedbrakes been immediately retracted and had the airplane pitch attitude been maintained at the stickshaker activation angle, the airplane could have climbed 300 feet above the initial impact point.

The B-757 speedbrake handle, which has an armed detent position to allow automatic deployment on landing, might be positioned to any desired level of spoiler panel deflection. When the automatic speedbrake feature is in use and the airplane is on the ground, advancement of either thrust lever from flight idle will cause any extended spoiler panels to stow. However, in flight, advancing the thrust levers has no effect on deployed speedbrakes. In addition, an amber center panel speedbrake light, an amber engine indicating and crew alerting (EICAS) SPEED BRAKES EXT message, the master caution light, and a beeper activate when speedbrakes are extended between 15 and 800 feet above ground level and flap extension is less than 25°.[4] The evidence in this accident indicates that the crew did not attempt to retract the speedbrakes and that the speedbrakes were extended throughout the attempted terrain avoidance maneuver.

For both a CFIT and a windshear escape maneuver, immediate retraction of the speedbrakes is needed to achieve the airplane's maximum climb performance. Yet this accident illustrates that during periods of high workload, flightcrews may not recognize that speedbrakes have remained extended; therefore, automatic stowage of the speedbrakes may be beneficial Examination of other large jet transport-category aircraft showed that 37 types do not have an automatic speedbrake stowing feature when full forward thrust is used, while at least eight jet airplanes, including the Airbus A-330 and A-340; the Fokker F28 and F100; and one corporate jet, have such a feature

However, Boeing engineers told Safety Board and Aeronautica Civil investigators that automatic retraction of the B-757 speedbrakes during a go-around may result in unwanted pitch excursions If the speedbrakes are stowed as the throttles advance, the airplane would pitch down as a result of the aerodynamic effects of stowing the speedbrakes The pilot would likely pull back on the control column to regain the desired pitch attitude as the engines began to spool up. The pilot effort and the increasing thrust could result in an undesirable upward pitch excursion. In fact, Boeing added compensating features to the B-777 to minimize such effects, which can occur during manual retraction of the speedbrakes while in flight (the B-777 does not have automatic speedbrake retraction).

Nevertheless, because of the potential safety benefits, the Safety Board believes that the FAA should evaluate the effects of automatically stowing the speedbrakes on existing airplanes when high power is commanded and determine the desirability of incorporating automatic

[4] For flap extension of 25° or more, the speedbrake caution indications will occur at any altitude

speedbrake retraction on these airplanes for windshear and terrain escape maneuvers, or other situations demanding maximum thrust and climb capability.

Further, because future airplanes can be equipped with features that compensate for potentially adverse aerodynamic characteristics when speedbrakes automatically retract, the Safety Board believes that the FAA should require that newly certified transport-category aircraft include automatic speedbrake retraction during windshear and GPWS escape maneuvers, or other situations demanding maximum thrust and climb capability.

For airplanes that do not have automatic retraction of the speedbrakes, the facts of this accident and the results of the initial performance study also suggest that improved GPWS escape maneuver procedures are needed. Boeing's B-757 Flight Crew Training Manual provides a procedure for monitoring the status of speedbrake deployment. The manual states that, "The Captain should keep his right hand on the speedbrake lever whenever they are used in-flight. This will preclude leaving the speedbrakes extended." AAL does not have a similar procedure. The Safety Board believes that the FAA should evaluate the Boeing procedure for guarding the speedbrake handle during periods of deployment, and require airlines to implement the procedure if it increases the speed of stowage or decreases the likelihood of forgetting to stow the speedbrakes in an emergency situation.

Further, neither the Boeing operations manual addressing terrain avoidance nor the AAL operating manual addressing GPWS escape procedures discusses the need to stow the speedbrakes during a GPWS escape maneuver. Also, Boeing places the terrain avoidance procedures in the Non-Normal Procedures section of its manual while AAL places the GPWS escape procedures in Section 13, "Flight Instruments," of its manual. While airlines often place such procedures in operational sections of their manuals, the Safety Board concludes that pilots would be better able to locate, be more familiar with, and retain the material more readily if it is placed in the non-normal sections of operating manuals. Therefore, the Safety Board believes that the FAA should evaluate the terrain avoidance procedures of air carriers operating transport-category aircraft to ensure that the procedures provide for the extraction of maximum escape performance and ensure that those procedures are placed in procedural sections of the approved operations manuals.

Data revealed that the first officer promptly initiated a nose-up elevator input after the GPWS warning activated, and continued the nose-up inputs until the stick shaker activated. Next, he immediately reduced the pitch attitude until the stick shaker stopped. He then increased the pitch attitude until the stick shaker again activated, and continued to increase the pitch attitude to the stall angle-of-attack. As noted, had the stick shaker activation angle been steadily maintained during the escape maneuver, the airplane may have climbed above the initial impact point. The evidence from this accident demonstrates that inadequacies in the use of the stick shaker as a primary indicator for angle-of-attack limited the first officer's ability to obtain the maximum climb performance possible from the airplane when it was most needed. Although the stick shaker presents effective tactile and aural indications of the angle of attack needed to achieve maximum performance of the airplane, angle-of-attack information should be presented in a visual and more readily interpretable format. Military aircraft have been equipped with angle-of-attack indicators for many years; however, these indicators are not required on civil air transport aircraft.

Presentation of angle-of attack information can enhance pilot control of the airplane during takeoffs and climbs, and during maneuvers such as engine-out procedures, holding, maximum range, GPWS encounters, windshear, maximum range, approach, and missed approach procedures The visual presentation of angle-of-attack information in transport-category aircraft, combined with pilot training in using this information to achieve maximum airplane climb performance, would enhance the ability of pilots to extract maximum performance from an airplane. Therefore, the Safety Board believes that the FAA should require that all transport-category aircraft present pilots with angle-of-attack information in a visual format, and that all air carriers train their pilots to use the information to obtain maximum possible airplane climb performance.

Although the number of CFIT accidents has decreased substantially since the installation of GPWS on transport-category aircraft following requirements to do so (by the FAA in 1975), and recommendations by the International Civil Aviation Organization (ICAO) in 1979, this accident and other recent accidents demonstrate that pilots need improved training for GPWS escape maneuvers.

The Safety Board recognizes the efforts already underway to further reduce the number of CFIT accidents. For example, an industry task force to prevent CFIT accidents internationally, which was formed in 1992, has sent several interim recommendations to ICAO. Although such educational efforts enhance flightcrew awareness of CFIT issues, they cannot provide the safety benefits of simulator-based training programs such as those that address windshear and rejected takeoffs. Simulator training is the best method for pilots to develop the knowledge and skills needed to extract maximum performance from large airplanes during a GPWS escape maneuver. Therefore, the Safety Board believes that the FAA should develop a CFIT training program that includes realistic simulator exercises comparable to the successful windshear and rejected takeoff training programs and make training in such a program mandatory for all pilots operating under 14 CFR Part 121.

**Retention of Critical Navigation Information in the FMS**

The Safety Board recognizes that the introduction of the FMS has considerably influenced the nature of flight operations. Pilots can control many aspects of a flight through the FMS and autopilot rather than directly through the airplane controls. The flightpath of FMS-equipped aircraft can be controlled through a variety of lateral and vertical automated flight modes of the autopilot, according to general parameters that are entered into the FMS. In addition, FMS-generated displays can present flightcrews with information on the airplane's systems and predicted future flightpath.

The CVR indicates that at 2135:28, the captain changed the FMS-programmed flightpath by commanding "direct to" to proceed to the Cali VOR, following his misinterpretation of the Cali controller's clearance. The "direct to" command caused the removal, between the airplane's present position and Cali, of all future waypoints programmed into the FMS and displayed on the EHSI, including TULUA, the navaid the pilots were to report passing. The evidence from the CVR indicates that neither pilot recognized that TULUA had been deleted from the programmed flightpath until the flight was considerably closer to Cali and had already passed TULUA. Because the crew was unaware that the flight had passed TULUA, it did not report this to the controllers. The removal of all programmed waypoints between the airplane's position and the navaid towards which the airplane was directed compromised the situational awareness[5] of the crew, particularly regarding the relative position of the airplane to waypoints and navaids critical to the approach.

Boeing had developed and implemented a change to the B-757 software that allows such waypoints to be retained in the EHSI map display of the programmed flightpath. However, this retrofit, part of a product improvement package for the airplane, had not been incorporated into the accident airplane, nor was it required to be. The Safety Board believes that the FAA should require all FMS-equipped aircraft that are not already capable of so doing, to be modified so that those waypoints between the airplane's position and the one towards which the airplane is proceeding are retained in the FMS control display unit (CDU) and FMS-generated flightpath following the execution of a command to the FMS to proceed direct to a waypoint.

**FMS Navigation Data**

The Jeppesen-Sanderson Company supplies both "hard-copy" (i.e., printed on paper) approach charts used for navigation, and navigation information for the electronic navigation data base in AAL's FMS-equipped aircraft. The presentation of the VOR-DME[6] approach to runway 19 at Cali on the approach chart differed in several significant ways from information displayed on the airplane's FMS and electronic flight information system (EFIS). For example, the DME fixes for the runway 19 approach were labeled on the approach chart as D-21 and D-16 but were labeled in the FMS as CF19 and FF19.[7] In addition, the ROZO NDB, a step-down fix[8] located 2.6 miles

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[5]Situational awareness has been defined as the "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." (Endsley, M.R., 1995. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors*. *37*, 65-84).

[6]Distance measuring equipment

[7]D-21 and D-16 refer to the points located 21 and 16 nautical miles, respectively, from the CLO VOR. They are listed as D-21 and D-16 on the approach chart for the VOR-DME approach to runway 19 at Cali and as CF 19 and FF 19 (for "capture fix" and "final fix" to runway 19) on the FMS-depicted approach The Boeing Operations Manual for B-757/767 aircraft defines CF as the final approach course fix and FF as the final approach fix

[8]A fix permitting additional descent within a segment of an instrument approach procedure by identifying a point at which a controlling obstacle has been safely overflown

from the runway, was prominently displayed on the approach chart and identified as "R," but was not displayed at all on the FMS-generated display.

The lack of commonality between instrument approach charts and FMS-generated displays is confusing and can increase pilot workload. Therefore, the Safety Board believes that the FAA should develop and implement standards to portray instrument approach criteria, including terminal environment information and navigational aids, on FMS-generated displays that match, as closely as possible, the corresponding information on instrument approach charts. Until such time as common standards are developed for FMS-generated displays and instrument approach charts, the Safety Board believes that the FAA should require Jeppesen-Sanderson to inform airlines operating FMS-equipped aircraft of each difference in the naming and/or portrayal of navigation information on FMS-generated and approach chart information, and require airlines to inform their pilots of these differences.

Further, the ROMEO NDB, a beacon located approximately 132 miles to the east-northeast of the accident site, transmitted on the same frequency, 274 kilohertz, and was also identified by "R," and the same Morse code identifier as was ROZO.[9]

The identification of "R" for both beacons ROMEO and ROZO could clearly confuse pilots, especially during a high workload situation. Specifically, a pilot attempting to select ROZO through the FMS while using the approach chart for reference may not realize that in the FMS, "R" designated ROMEO while on the approach chart, "R" designated ROZO. Executing a command to the FMS directing the airplane to the designator "R" would direct it away from ROZO towards the ROMEO beacon, located near Bogota.

Pilots can use two cues from the FMS to identify beacons. The first cue, using the latitude and longitude coordinates of beacons identified by that letter (which are presented on the CDU of the FMS in the order of increasing distance from the airplane) can be time-consuming and difficult to use during high workload flight phases. The second cue, examining the projected flightpath to that beacon on the map display of the EHSI, is easier to use and less prone to error.

Regardless, beacons with common identifiers introduce a potential source of error to pilots of automated aircraft. The investigation found numerous NDB navigation stations with common single letter identification codes including 28 NDBs, identified only as "R," outside of the United States.[10] Although ROMEO and ROZO were the only pair with common frequencies, three other pairs of NDBs identified as "R" were found close enough to each other that the displayed latitude/longitude coordinates appeared similar before closer and more detailed examination.

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[9] ROZO latitude/longitude - N03 35.8/W076 22.5 --- ROMEO latitude/longitude - N04 40.7/W074 06.3.

[10] In the United States, there are only two remaining single letter NDB stations; the letter "H" is on an island in the Florida Keys, and the letter "F" is on a Farrallon island, located to the west of San Francisco.

The Safety Board is concerned that pilots may not be aware of the hazards associated with FMS selection of waypoints with common identifiers, and as a result, they may make incorrect inputs into the FMS. Therefore, the Safety Board believes that the FAA should inform pilots of FMS-equipped aircraft of the hazards of selecting navigation stations with common identifiers when operating outside of the United States and that verification of the correct identity and coordinates of FMS-waypoints is required at all times.

**Portraying Terrain Information--FMS**

In FMS-equipped aircraft, the portrayal of flightpath, (in Boeing aircraft by means of a magenta colored line), is so accurate and informative that pilots are permitted to rely on it as the primary means of navigation. However, unlike hard-copy charts that have been revised to graphically portray terrain, FMS-generated displays do not present terrain information and pilots who are accustomed to relying exclusively on FMS-generated displays for navigation information can, over time, lose awareness of the relative proximity of terrain. Therefore, the Safety Board believes that the FAA should require pilots operating under 14 CFR Part 121 to have open and easily accessible the approach and navigation charts applicable to each phase of flight before each phase is reached.

In addition, recent technological advances (i.e., enhanced GPWS) allow the presentation of terrain information on FMS-generated displays and weather radar displays. The Safety Board has learned that AAL has ordered enhanced GPWS for installation on its fleet. The system uses a digital terrain elevation data base and airplane three-dimensional position to provide pilots with both an earlier warning of terrain than on present GPWS-aircraft and a visual display of the threatening terrain. Because this equipment may considerably reduce the potential for CFIT accidents and thereby enhance flight safety, the Safety Board believes that the FAA should examine the effectiveness of the enhanced ground proximity warning equipment and, if found effective, require all transport-category aircraft to be equipped with enhanced ground proximity warning equipment that provides pilots with an early warning of terrain.

**Portraying Terrain Information--Charts**

Before the accident, Jeppesen-Sanderson was changing portrayal of terrain on the charts and maps that it supplied to its customers, in accordance with new criteria that it had established. According to the new criteria, terrain is portrayed using graphics similar to those used in topographic charts, with colors added to enhance the prominence of terrain and heighten its contrast with other information on the chart. These criteria differed for approach charts and area charts. On approach charts, terrain would be displayed if it was above 2,000 feet within 6 miles of the airport, and on local area charts, terrain would be displayed if it was more than 4,000 feet above the planned view of the airport. Because the applicable criterion was not met in the VOR DME runway 19 approach chart, terrain was not graphically presented on it. Although the criterion was met with regard to the Cali local area chart, at the time of the accident the company had not yet converted that chart to the new format.

Consequently, it is likely that the crew did not have a chart available that graphically depicted the high terrain on either side of the descent into Cali.

Graphic information can readily present the proximity of terrain to a flightcrew and is an effective means of presenting critical information to flightcrews quickly and without extensive interference from other tasks. The Safety Board notes the efforts of Jeppesen to upgrade its approach charts to present such information in the absence of a requirement to do so. Had this portrayal of terrain been available to the crew, and had the crew referred to charts containing this information, it is possible that the crew would have been aware of the proximity of terrain to the flightpath, and the accident could have been avoided. Therefore, the Safety Board believes that the FAA should require that all approach and navigation charts graphically present terrain information.

Over time, repeated exposure to routine flight operations into potentially hazardous environments can create complacency as pilots become acclimated to the environment, and the perceived need to maintain constant vigilance against the unique hazards of certain operations is diminished. In this accident, the evidence suggests that both pilots failed to take the extra precautions that are needed when operating in a mountainous area that lacks ATC radar coverage, such as Cali. In domestic United States airspace, an approach controller without access to ATC radar would be unlikely to issue a clearance to proceed directly to a fix, and would expect pilots to execute all steps of an instrument approach. Therefore, to ensure that pilots are aware of and act on the absence of radar coverage, the Safety Board believes that the FAA should require that approach charts to airports that do not have radar coverage available at the time of the publication of the chart prominently state, on the chart, that radar coverage is unavailable.

**Naming Standard Terminal Arrival Routes**

The crew of flight 965 may also have been confused because the standard terminal arrival route (STAR) they were attempting to execute had been designated the ROZO 1 Arrival. This arrival was named by the NDB and step down fix located just before runway 19, unlike most STARs that are named by the fix at the beginning of the arrival route. Had this naming convention been followed, the designator for the STAR would have been TULUA. CVR evidence reveals that the crew may have expected the standard STAR naming convention to be used with respect to the ROZO 1 Arrival and may have incorrectly believed that ROZO was located at the beginning of the route.

ICAO Annex 11, "Air Traffic Services," recommends that STARS be identified according to Appendix 3, paragraph 2.1.2, which states:

> The basic indicator (of a STAR or standard instrument departure) should be the name or name code of the significant point where a standard departure route terminates or a standard arrival route begins.

Further, the FAA provides similar guidance, in Order 7100.9B, "Standard Terminal Arrival," paragraph 8.b.(2) which states, in part:

> The STAR transition code is assigned by using the NAVAID identifier or intersection name marking the beginning of the transition, following by a dot, followed by the identifier/name of the STAR.

Had the ROZO 1 arrival been designated the TULUA 1 arrival, a clear distinction would have been established between beginning and ending points of the arrival. This would likely have reduced or eliminated any confusion by the crew regarding the location of the beginning of the STAR. Therefore, the Safety Board believes that the FAA should review, with ICAO member states, the naming conventions used for standard instrument departures (SIDs) and STARs, and urge member states with SIDs and STARs that do not follow the ICAO naming convention to rename them in accordance with the ICAO recommendation.

**ATC/Flightcrew Interaction**

As the flight approached Cali, the captain's questions to the controller suggest that the crew was confused about its situation. For example, at 2137:29, the captain asked the controller if flight 965 could "go direct to ROZO and then do the ROZO arrival," suggesting that he did not recognize that the STAR began at TULUA. The captain had, in effect, asked the controller for permission to go almost to the runway, reverse course, proceed to the very beginning of the approach, and then execute the approach. The subsequent communication at 2140:01, when the captain again asked the controller "...You want us to go to TULUA and then do the ROZO uh, to uh, the runway, right to runway one nine?" also made little sense as he had already crossed TULUA and therefore would have had to reverse course according to his question. Despite this evidence of confusion, the controller did not directly respond to the captain's request, reiterating the clearance instead.

The interaction between the captain and the Cali controller served to confuse rather than enlighten the crew. While pilot-ATC communications are designed primarily to assure that the airspace, runway, and taxiway ahead of the airplane are free of conflicting traffic, this assurance is dependent upon the common understanding by each party of the intent underlying the other's communication. The Cali controller told investigators that he was unable to understand the intent of the captain's request; thus he could not provide a meaningful answer and alleviate the captain's confusion. The controller explained that his communications with the captain were hindered by his lack of English fluency, which prevented him from determining the reason for the captain's question and from providing the information the captain critically needed, i.e., that the approach began at TULUA and not at ROZO.

Controllers are not given training on how to clarify to flightcrews misunderstandings regarding flight procedures. In addition, in certain cultures airline captains are accorded a level of status such that air traffic controllers may be unwilling to question an airline pilot who may appear to be confused. In this accident, the combination of language and cultural differences appears to have prevented effective interaction between the controller and the pilot.

Such interaction could have enabled the controller to determine the extent of the pilots' confusion regarding the approach, and perhaps provided assistance to reduce their confusion.

It is essential that pilots and controllers work together to assure that airspace separation is maintained, and that situational awareness regarding critical features of the airspace has been obtained. Effective interaction between pilots and controllers is especially critical in non-radar environments, in which there are few redundant features available to prevent errors in situational awareness from becoming catastrophic accidents. Therefore, the Safety Board believes that the FAA should develop, with air traffic authorities of member states of ICAO, a program to enhance controllers' fluency in common English-language phrases and interaction skills sufficient to assist pilots in obtaining situational awareness about critical features of the airspace, particularly in non-radar environments.

## Training in CRM and Situational Awareness

The FAA has encouraged airlines to implement effective CRM programs and has mandated them to be a fundamental part of its advanced qualification program (AQP). The FAA has issued Advisory Circular (AC) No. 120-51B, which provides guidance to airlines on elements needed for an effective CRM program and identifies topics that should be included in a CRM program. These include the following: communications processes and decision behavior; briefings; inquiry/advocacy/assertion, crew self-critique; conflict resolution; communications and decisionmaking; teambuilding and maintenance; and individual factors/stress reduction. Within the topic of teambuilding, the AC suggests that workload management and situational awareness be addressed so that, "the importance of maintaining awareness of the operational environment and anticipating contingencies..." is addressed.

Consistent with the intent of the AC, beginning in 1994 AAL applied information from the report of an accident similar to this[11] in CRM training sessions attended by over 95 percent of AAL pilots, to inform its pilots of potential risks of piloting highly automated aircraft. It is likely that the pilots of flight 965 learned of that accident in their recurrent CRM training. In the recurrent CRM program, AAL informed its pilots that they should use charts and either partially or completely disengage the FMS when they believe that the FMS is exacerbating and not alleviating a confusing or difficult situation. Delta Airlines has developed a similar course, given to all pilots before they first transition to a glass cockpit airplane, that provides comparable guidance.

Although the pilots of flight 965 articulated misgivings several times during the approach, neither one apparently recognized that they had lost situational awareness. The evidence indicates that this crew was given background material and information necessary to avoid this accident, including information on the hazardous terrain in South America, the need for maintaining responsibility for being aware of aircraft position at all times, the lack of radar coverage, the overreliance on automation for position awareness, among others, but during a

[11]Aviation Accident Report, Thai Airways International, Ltd. Airbus Industries A310-304, HS-TID, Near Katmandu, Nepal, 23 NNE, 31 July 1992. His Majesty's Government of Nepal, June 1993.

stressful situation when it was most needed, the guidance was not applied, possibly because the pilots were unable to recognize the parallels of the situation they were experiencing with the guidance and information they had been provided.

This accident demonstrates the need for training that effectively provides pilots with the ability to recognize when they have lost or have failed to obtain situational awareness. Therefore, the Safety Board believes that the FAA should revise AC 120-51B to include specific guidance on methods to effectively train pilots to recognize cues that indicate that they have not obtained situational awareness, and provide effective measures to obtain that awareness.

Therefore, as a result of the investigation of this accident, and with the concurrence of the Aeronautica Civil of Colombia, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Evaluate the effects of automatically stowing the speedbrakes on existing airplanes when high power is commanded and determine the desirability of incorporating automatic speedbrake retraction on these airplanes for windshear and terrain escape maneuvers, or other situations demanding maximum thrust and climb capability. (Class II, Priority Action) (A-96-90)

> Require that newly certified transport-category aircraft include automatic speedbrake retraction during windshear and ground proximity warning system escape maneuvers, or other situations demanding maximum thrust and climb capability. (Class II, Priority Action) (A-96-91)

> Evaluate the Boeing Commercial Airplane Group procedure for guarding the speedbrake handle during periods of deployment, and require airlines to implement the procedure if it increases the speed of stowage or decreases the likelihood of forgetting to stow the speedbrakes in an emergency situation. (Class II, Priority Action) (A-96-92)

> Evaluate the terrain avoidance procedures of air carriers operating transport-category aircraft to ensure that the procedures provide for the extraction of maximum escape performance and ensure that those procedures are placed in procedural sections of the approved operations manuals. (Class II, Priority Action) (A-96-93)

> Require that all transport-category aircraft present pilots with angle-of-attack information in a visual format, and that all air carriers train their pilots to use the information to obtain maximum possible airplane climb performance (Class II, Priority Action) (A-96-94)

> Develop a controlled flight into terrain training program that includes realistic simulator exercises comparable to the successful windshear and rejected takeoff

training programs and make training in such a program mandatory for all pilots operating under 14 CFR Part 121.(Class II, Priority Action) (A-96-95)

Require all flight management system (FMS)-equipped aircraft, that are not already capable of so doing, to be modified so that those fixes between the airplane's position and the one towards which the airplane is proceeding are retained in the FMS control display unit and FMS-generated flightpath following the execution of a command to the FMS to proceed direct to a fix. (Class II, Priority Action) (A-96-96)

Inform pilots of flight management system (FMS)-equipped aircraft of the hazards of selecting navigation stations with common identifiers when operating outside of the United States and that verification of the correct identity and coordinates of FMS-generated waypoints data is required at all times.(Class II, Priority Action) (A-96-97)

Develop and implement standards to portray instrument approach criteria, including terminal environment information and navigational aids, on FMS-generated displays that match, as closely as possible, the corresponding information on instrument approach charts.(Class II, Priority Action) (A-96-98)

Until such time as common standards are developed for flight management system (FMS)-generated displays and instrument approach charts, require the Jeppesen-Sanderson Company to inform airlines operating FMS-equipped aircraft of each difference in the naming and/or portrayal of navigation information on FMS-generated and approach chart information, and require airlines to inform their pilots of these differences. (Class II, Priority Action) (A-96-99)

Require pilots operating under 14 CFR Part 121 to have open and easily accessible the approach and navigation charts applicable to each phase of flight before each phase is reached. (Class II, Priority Action) (A-96-100)

Examine the effectiveness of the enhanced ground proximity warning equipment and, if found effective, require all transport-category aircraft to be equipped with enhanced ground proximity warning equipment that provides pilots with an early warning of terrain. (Class II, Priority Action) (A-96-101)

Require that all approach and navigation charts graphically present terrain information. (Class II, Priority Action) (A-96-102)

Require that approach charts to airports that do not have radar coverage available at the time of the publication of the chart prominently state, on the chart, that radar coverage is unavailable. (Class II, Priority Action) (A-96-103)

Review, with the International Civil Aviation Organization (ICAO) member states, the naming conventions used for standard instrument departures (SIDs) and standard terminal arrival routes (STARs), and urge member states with SIDs and STARs that do not follow the ICAO naming convention to rename them in accordance with the ICAO recommendation. (Class II, Priority Action) (A-96-104)

Develop, with air traffic authorities of member states of the International Civil Aviation Organization, a program to enhance controllers' fluency in common English-language phrases and interaction skills sufficient to assist pilots in obtaining situational awareness about critical features of the airspace, particularly in non-radar environments. (Class II, Priority Action) (A-96-105)

Revise Advisory Circular 120-51B to include specific guidance on methods to effectively train pilots to recognize cues that indicate that they have not obtained situational awareness, and provide effective measures to obtain that awareness. (Class II, Priority Action) (A-96-106)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman