FLIGHT SAFETY FOUNDATION

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Controlled Flight Into Terrain Korean Air Flight 801 Boeing 747-300, HL7468 Nimitz Hill, Guam August 6, 1997

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In This Issue

Cover: On Aug. 6, 1997, Korean Air Flight 801, a Boeing 747-300, struck Nimitz Hill during a nonprecision instrument approach to Guam International Airport.
Photo: U.S. National Transportation Safety Board

Foreword

In fulfilling its mission to disseminate aviation safety information to a global audience, Flight Safety Foundation (FSF) usually publishes condensed versions of official accident reports in *Accident Prevention*. These easy-to-read articles are designed to provide readers with essential information that can help prevent other accidents. The U.S. National Transportation Safety Board (NTSB) final report on the Korean Air Boeing 747 accident in Guam, however, is an exception to this policy; the comprehensive report has been published in its entirety in this issue of *Flight Safety Digest*. (Minor changes by FSF editorial staff are noted in brackets with an asterisk: [*].)

The NTSB report provides an extraordinary depth of useful information that highlights various issues often associated with controlled-flight-into-terrain (CFIT) accidents and approach-and-landing accidents (ALAs). Moreover, the report includes the following information from the Foundation:

- Findings of the international FSF CFIT Task Force, created in 1992, and the international Approach-and-landing Accident Reduction (ALAR) Task Force, created in 1996;

- Comments presented by a member of both the CFIT and ALAR task forces during NTSB public hearings on the Korean Air accident;

- The availability of education and training aids, which were developed by the FSF task forces to prevent CFIT and ALAs; and,

- Preliminary conclusions and recommendations of the ALAR task force (the final conclusions and recommendations were published in the November–December 1998 and January–February 1999 special issue of *Flight Safety Digest*: "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents").

The many volunteers from industry who have served — and continue to serve — on FSF task forces deserve the recognition for collecting and analyzing accident data, and developing recommendations and tools to prevent CFIT and ALAs. Their groundbreaking work, which has resulted in the world's foremost information on these types of accidents, continues to be cited by civil aviation authorities, the news media and the aviation industry.

Stuart Matthews
Chairman, President and CEO
Flight Safety Foundation

May 2000

Aircraft Accident Report

Controlled Flight Into Terrain
Korean Air Flight 801
Boeing 747-300, HL7468
Nimitz Hill, Guam
August 6, 1997

NTSB/AAR-00/01
PB00-910401
Notation 6952B
Adopted January 13, 2000

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

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Abbreviations

AC	advisory circular
ADF	automatic direction finder
ADI	attitude director indicator
AFB	Air Force Base
agl	above ground level
AIG	Accident Investigation Group
ALA	approach and landing accident
ALPA	Air Line Pilots Association
ARFF	aircraft rescue and firefighting
ARTS	Automated Radar Terminal System
ASR	Airport Surveillance Radar
ATC	air traffic control
ATCT	air traffic control tower
ATIS	automatic terminal information service
ATP	airline transport pilot
CAA	civil aviation authority
CAMI	Civil Aeromedical Institute
CDI	course deviation indicator
CERAP	Combined Center/Radar Approach Control
CFIT	controlled flight into terrain
CFR	Code of Federal Regulations
CRM	crew resource management
CVR	cockpit voice recorder
D-BRITE	digital bright radar indicator tower equipment
DFDR	digital flight data recorder
DH	decision height
DME	distance measuring equipment
DOD	Department of Defense
DOT	Department of Transportation
DOT/IG	Department of Transportation Office of Inspector General
EARTS	En route Automated Radar Tracking System
EMT	emergency management technician
EU	European Union
FAA	Federal Aviation Administration
FAF	final approach fix
FAR	Federal Aviation Regulation
FD	flight director
FDAU	flight data acquisition unit
FDR	flight data recorder
F/E	flight engineer
FMA	flight mode annunciator
FMS	flight management system
FSF	Flight Safety Foundation
GCD	Guam Civil Defense
GFD	Guam Fire Department
GPS	global positioning system
GPWS	ground proximity warning system
GS	glideslope
HAT	height above touchdown
Hg	Mercury
HSI	horizontal situation indicator
Hz	Hertz
IAF	initial approach fix
IASA	International Aviation Safety Assessment
ICAO	International Civil Aviation Organization

IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
IOE	initial operational experience
KCAB	Korean Civil Aviation Bureau
kg	kilogram
LOC	localizer
LOFT	line-oriented flight training
MAP	missed approach point
MDA	minimum descent altitude
MHz	megahertz
MOCT	Ministry of Construction and Transport
MOU	memorandum of understanding
MSAW	minimum safe altitude warning
msl	mean sea level
NASA	National Aeronautics and Space Administration
NDB	nondirectional beacon
nm	nautical mile
NOTAM	Notice to Airmen
NPRM	notice of proposed rulemaking
NWS	National Weather Service
OSC	on-scene commander
OST	Office of the Secretary of Transportation
PAPI	precision approach path indicator
PF	pilot flying
PIC	pilot-in-command
PNF	pilot not flying
POI	principal operations inspector
SIGMET	Significant Meteorological Information
SOF	supervisor of flying
SOP	standard operating procedure
STAR	standard terminal arrivals
STARS	Standard Terminal Automation Replacement System
TACAN	tactical air control and navigation
TAESA	Transportes Aereos Ejecutivos, S.A.
TAF	terminal aerodrome forecast
TAWS	terrain awareness and warning system
TCAS	traffic alert and collision avoidance system
TERPS	Terminal Instrument Procedures
TOD	top of descent
TRACON	terminal radar approach control
TSA	time since awakening
TSO	technical standard order
UTC	coordinated universal time
VASI	visual approach slope indicator
VFR	visual flight rules
VHF	very high frequency
VMC	visual meteorological conditions
VNAV	vertical navigation
VOR	very high frequency omnidirectional radio range
WSR-88D	Weather Surveillance Radar-1988, Doppler

Executive Summary

On August 6, 1997, about 0142:26 Guam local time, Korean Air flight 801, a Boeing 747-3B5B (747-300), Korean registration HL7468, operated by Korean Air Company, Ltd., crashed at Nimitz Hill, Guam. Flight 801 departed from Kimpo International Airport, Seoul, Korea, with 2 pilots, 1 flight engineer, 14 flight attendants, and 237 passengers on board. The airplane had been cleared to land on runway 6 Left at A.B. Won [* Pat] Guam International Airport, Agana, Guam, and crashed into high terrain about 3 miles southwest of the airport. Of the 254 persons on board, 228 were killed, and 23 passengers and 3 flight attendants survived the accident with serious injuries. The airplane was destroyed by impact forces and a postcrash fire. Flight 801 was operating in U.S. airspace as a regularly scheduled international passenger service flight under the Convention on International Civil Aviation and the provisions of 14 Code of Federal Regulations Part 129 and was on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable cause of the Korean Air flight 801 accident was the captain's failure to adequately brief and execute the nonprecision approach and the first officer's and flight engineer's failure to effectively monitor and cross-check the captain's execution of the approach. Contributing to these failures were the captain's fatigue and Korean Air's inadequate flight crew training. Contributing to the accident was the Federal Aviation Administration's (FAA) intentional inhibition of the minimum safe altitude warning system (MSAW) at Guam and the agency's failure to adequately manage the system.

The safety issues in this report focus on flight crew performance, approach procedures, and pilot training; air traffic control, including controller performance and the intentional inhibition of the MSAW system at Guam; emergency response; the adequacy of Korean Civil Aviation Bureau (KCAB) and FAA oversight; and flight data recorder documentation. Safety recommendations concerning these issues are addressed to the FAA, the Governor of the Territory of Guam, and the KCAB.

1. Factual Information

1.1 History of Flight

On August 6, 1997, about 0142:26 Guam local time,[1] Korean Air flight 801, a Boeing 747-3B5B (747-300), Korean registration HL7468, operated by Korean Air Company, Ltd., crashed at Nimitz Hill, Guam.[2] Flight 801 departed from Kimpo International Airport, Seoul, Korea, with 2 pilots, 1 flight engineer, 14 flight attendants, and 237 passengers[3] on board. The airplane had been cleared to land on runway 6 Left at A.B. Won [* Pat] Guam International Airport, Agana, Guam, and crashed into high terrain about 3 miles southwest of the airport. Of the 254 persons on board, 228 were killed,[4] and 23 passengers and 3 flight attendants survived the accident with serious injuries.[5] The airplane was destroyed by impact forces and a postcrash fire. Flight 801 was operating in U.S. airspace as a regularly scheduled international passenger service flight under the Convention on International Civil Aviation and the provisions of 14 Code of Federal Regulations (CFR) Part 129 and was on an instrument flight rules (IFR) flight plan.

According to Korean Air company records, the flight crew arrived at the dispatch center in the Korean Air headquarters building in Seoul about 2 hours before the scheduled departure time of 2105 (2005 Seoul local time) on August 5, 1997. The original flight plan for flight 801 listed a different captain's name. The captain aboard the accident flight had initially been scheduled to fly to Dubai, United Arab Emirates; however, because the accident captain did not have adequate rest for that trip, he was reassigned the shorter trip to Guam.[6]

According to Korean Air personnel, the flight crewmembers collected the trip paperwork, conducted a self-briefing, and received a briefing from the assigned supervisor of flying (SOF).[7] Flight 801 departed the gate about 2127 and was airborne about 2153.

According to the cockpit voice recorder (CVR), the captain was performing the pilot-flying (PF) duties, and the first officer was performing the pilot-not-flying (PNF) duties. Upon arrival to the Guam area, the first officer made initial contact with the Federal Aviation Administration's (FAA) Guam Combined Center/Radar Approach Control (CERAP) controller about 0103:18, when the airplane was level at 41,000 feet mean sea level (msl) and about 240 nautical miles (nm) northwest of the NIMITZ VOR/DME.[8]

About 0105:00, the CERAP controller told flight 801 to expect to land on runway 6L, and the first officer acknowledged the transmission. About 0110:00, the controller instructed flight 801 to " … descend at your discretion maintain two thousand six hundred [feet msl]." The first officer responded, " … descend two thousand six hundred pilot discretion."

About 0111:51, the CVR[9] recorded the captain briefing the first officer and the flight engineer about the approach and landing at Guam. The captain stated:

> I will give you a short briefing … ILS [instrument landing system[10]] is one one zero three … NIMITZ VOR is one one five three, the course zero six three, since the visibility is six, when we are in the visual approach, as I said before, set the VOR on number two and maintain the VOR for the TOD [top of descent],[11] I will add three miles from the VOR, and start descent when we're about one hundred fifty five miles out. I will add some more speed above the target speed. Well, everything else is all right. In case of go-around, since it is VFR [visual flight rules], while staying visual and turning to the right … request a radar vector … if not, we have to go to

FLAKE[12] … since the localizer glideslope is out,[13] MDA [minimum descent altitude] is five hundred sixty feet and HAT [height above touchdown] is three hundred four feet … .

About 0113:33, the CVR recorded the captain saying, “we better start descent;” shortly thereafter, the first officer advised the controller that flight 801 was “leaving four one zero for two thousand six hundred.” The controller acknowledged the transmission.

The CVR recorded the captain making several remarks related to crew scheduling and rest issues. About 0120:01, the captain stated, “if this round trip is more than a nine hour trip, we might get a little something … with eight hours, we get nothing … eight hours do not help us at all.”[14] The captain also stated that “they make us work to maximum, up to maximum … .” About 0120:28, the captain further stated, “probably this way [unintelligible words], hotel expenses will be saved for cabin crews, and maximize the flight hours. Anyway, they make us [747] classic guys work to maximum.”[15] About 0121:13, the captain stated, “eh … really … sleepy.”

About 0121:59, the first officer stated, “captain, Guam condition is no good.” About 0122:06, the CERAP controller informed the flight crew that the automatic terminal information service (ATIS) information Uniform[16] was current and that the altimeter setting was 29.86 inches of mercury (Hg). About 0122:11, the first officer responded, “Korean eight zero one is checked uniform;” his response did not acknowledge the altimeter setting. About 0122:26, the captain stated, “uh … it rains a lot.” About 0123:45, the captain stated, “request twenty miles deviation later on … to the left as we are descending.” About 0124:02, the first officer questioned, “don’t you think it rains more? in this area, here?” The captain then stated, “left, request deviation” and “one zero mile.” About 0124:30, the controller approved the first officer’s request to deviate “ … one zero mile left of track [for weather].”

The CVR then recorded about 6 minutes of discussion among the flight crew regarding the weather conditions and the deviation around the weather. About 0126:25, the flight engineer stated, “it’s Guam, Guam.” About 0131:17, the first officer reported to the CERAP controller that the airplane was “ … clear of Charlie Bravo [cumulonimbus clouds]” and requested “radar vectors for runway six left.” The controller instructed the flight crew to fly a heading of 120°. After this transmission, the flight crew performed the approach checklist and verified the radio frequency for the ILS to runway 6L.

About 0138:49, the CERAP controller instructed flight 801 to “ … turn left heading zero nine zero join localizer;” the first officer acknowledged this transmission. At that time, flight 801 was descending through 2,800 feet msl with the flaps extended 10° and the landing gear up. About 0139:30, the first officer said, “glideslope [several unintelligible words] … localizer capture [several unintelligible words] … glideslope … did.” About 0139:44, the controller stated, “Korean Air eight zero one cleared for ILS runway six left approach … glideslope unusable.”[17] The first officer responded, “Korean eight zero one roger … cleared ILS runway six left;” his response did not acknowledge that the glideslope was unusable.

According to the CVR, about 0139:55 the flight engineer asked, “is the glideslope working? glideslope? yeh?” One second later, the captain responded, “yes, yes, it’s working.” About 0139:58, an unidentified voice in the cockpit stated, “check the glideslope if working?” This statement was followed 1 second later by an unidentified voice in the cockpit asking, “why is it working?” About 0140:00, the first officer responded, “not useable.”

About 0140:06, the CVR recorded the sound of the altitude alert system[18] chime. According to information from the flight data recorder (FDR), the airplane began to descend about 0140:13 from an altitude of 2,640 feet msl at a point approximately 9 nm from the runway 6L threshold (5.7 nm from the NIMITZ VOR). About 0140:22, an unidentified voice in the cockpit said, “glideslope is incorrect.” About 0140:33, as the airplane was descending through 2,400 feet msl, the first officer stated, “approaching fourteen hundred [feet].” About 4 seconds later, when the airplane was about 8 nm from the runway 6L threshold, the captain stated, “since today’s glideslope condition is not good, we need to maintain one thousand four hundred forty [feet]. please set it.” An unidentified voice in the cockpit then responded, “yes.” About 0140:42, the CERAP controller instructed flight 801 to contact the Agana control tower; the first officer acknowledged the frequency change. The first officer contacted the Agana tower about 0140:55 and stated, “Korean air eight zero one intercept the localizer six left.” Shortly after this transmission, the CVR again recorded the sound of the altitude alert chime, and the FDR data indicated that the airplane was descending below 2,000 feet msl at a point 6.8 nm from the runway threshold (3.5 nm from the VOR).

About 0141:01, the Agana tower controller cleared flight 801 to land. About 0141:14, as the airplane was descending through 1,800 feet msl, the first officer acknowledged the landing clearance, and the captain requested 30° of flaps. No further communications were recorded between flight 801 and the Agana control tower.

About 0141:31, the first officer called for the landing checklist. About 0141:33, the captain said, “look carefully” and “set five hundred sixty feet” (the published MDA). The first officer replied “set,” the captain called for the landing checklist, and the flight engineer began reading the landing checklist. About 0141:42, as the airplane descended through 1,400 feet msl, the CVR recorded the sound of the ground proximity warning system (GPWS)[19] radio altitude callout “one thousand [feet].” One second later, the captain stated, “no flags gear and flaps,” to which the flight engineer responded, “no flags gear and flaps.”

About 0141:46, the captain asked, "isn't glideslope working?" There was no indication on the CVR that the first officer and flight engineer responded to this question. About 0141:48, the captain stated, "wiper on."[20] About 0141:53, the CVR recorded the sound of the windshield wipers starting. The windshield wipers remained on throughout the remainder of the flight.

About 0141:53, the first officer again called for the landing checklist, and the flight engineer resumed reading the checklist items. About 0141:59, when the airplane was descending through 1,100 feet msl at a point about 4.6 nm from the runway 6L threshold (approximately 1.3 nm from the VOR), the first officer stated "not in sight?" One second later, the CVR recorded the GPWS radio altitude callout of "five hundred [feet]." According to the CVR, about 2 seconds later the flight engineer stated "eh?" in an astonished tone of voice.

About 0142:05, the captain and flight engineer continued the landing checklist. About 0142:14, as the airplane was descending through 840 feet msl and the flight crew was performing the landing checklist, the GPWS issued a "minimums minimums" annunciation followed by a "sink rate" alert[21] about 3 seconds later. The first officer responded, "sink rate okay" about 0142:18; FDR data indicated that the airplane was descending 1,400 feet per minute at that time.

About 0142:19, as the airplane descended through 730 feet msl, the flight engineer stated, "two hundred [feet]," and the first officer said, "let's make a missed approach." About 1 second later, the flight engineer stated, "not in sight," and the first officer said, "not in sight, missed approach." About 0142:22, as the airplane descended through approximately 680 feet msl, the FDR showed that the control column position began increasing (nose up) at a rate of about 1° per second, and the CVR indicated that the flight engineer stated, "go around." When the captain stated "go around" about 1 second later, the airplane's engine pressure ratios and airspeed began to increase. However, the rate of nose-up control column deflection remained about 1° per second. At 0142:23.77, as the airplane descended through 670 feet msl, the CVR recorded the sound of the autopilot disconnect warning. At 0142:24.05, the CVR began recording sequential GPWS radio altitude callouts of "one hundred … fifty … forty … thirty … twenty [feet]." About 0142:26, the airplane impacted hilly terrain at Nimitz Hill, Guam, about 660 feet msl and about 3.3 nm from the runway 6L threshold. FDR data indicated that, at the time of initial ground impact, the pitch attitude of the airplane was increasing through 3°. The accident occurred at 13° 27.35 minutes north latitude and 144° 43.92 minutes east longitude during the hours of darkness. The CVR stopped recording about 0142:32.

Figure 1 [* page 12] shows the instrument approach chart for the Guam runway 6L ILS procedure that was in effect at the time of the accident. Figures 2 [* page 13] and 3 [* page 14] show FDR information for the last 5 1/2 minutes of flight, along with CVR comments and sounds and air traffic control (ATC) data.

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	3	11	214	0	**228**
Serious	0	3	23	0	**26**
Minor	0	0	0	0	**0**
None	0	0	0	0	**0**
Total	**3**	**14**	**237**	**0**	**254**

1.3 Damage to Airplane

The airplane was destroyed by impact forces and a postcrash fire. The estimated value of the airplane was about $60 million.

1.4 Other Damage

The accident caused extensive ground scarring and fire damage to trees and foliage along the wreckage path and in the immediate vicinity of the main wreckage area. Also, a 12-inch fuel oil pipeline located along a vehicle access road that services the NIMITZ VOR was severed when it was struck by the airplane. The severed pipeline spilled about 1,000 gallons of oil in a localized area.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 42, was hired by Korean Air on November 2, 1987. He was previously a pilot in the Republic of Korea Air Force. He held an Airline Transport Pilot (ATP) certificate issued by the Korean Ministry of Construction and Transport (MOCT)[22] on April 19, 1992, with type ratings in the Boeing 727 and 747. The captain qualified as a 727 first officer on December 19, 1988, and as a 747 first officer on February 13, 1991. He upgraded to 727 captain on December 27, 1992, and 747 captain on August 20, 1995. The captain held Korean and FAA First Class Airman Medical certificates, both issued on March 13, 1997, without limitations.

According to Korean Air records, the captain had accumulated a total of 8,932 hours of flight time, 2,884 hours as a military pilot and 6,048 hours as a civilian pilot. He had logged a total of 1,474 and 1,718 hours as a 747 first officer and captain, respectively. Also, Korean Air's 747 chief pilot stated, in a postaccident interview, that the captain had received a Flight Safety Award in May 1997 from the company president for successfully handling an in-flight emergency involving a 747 engine failure at a low altitude.

The captain had flown 235, 144, 90, and 17 hours in the last 90, 60, 30, and 7 days, respectively, before the accident. Between December 1992 and August 1993, he had flown from

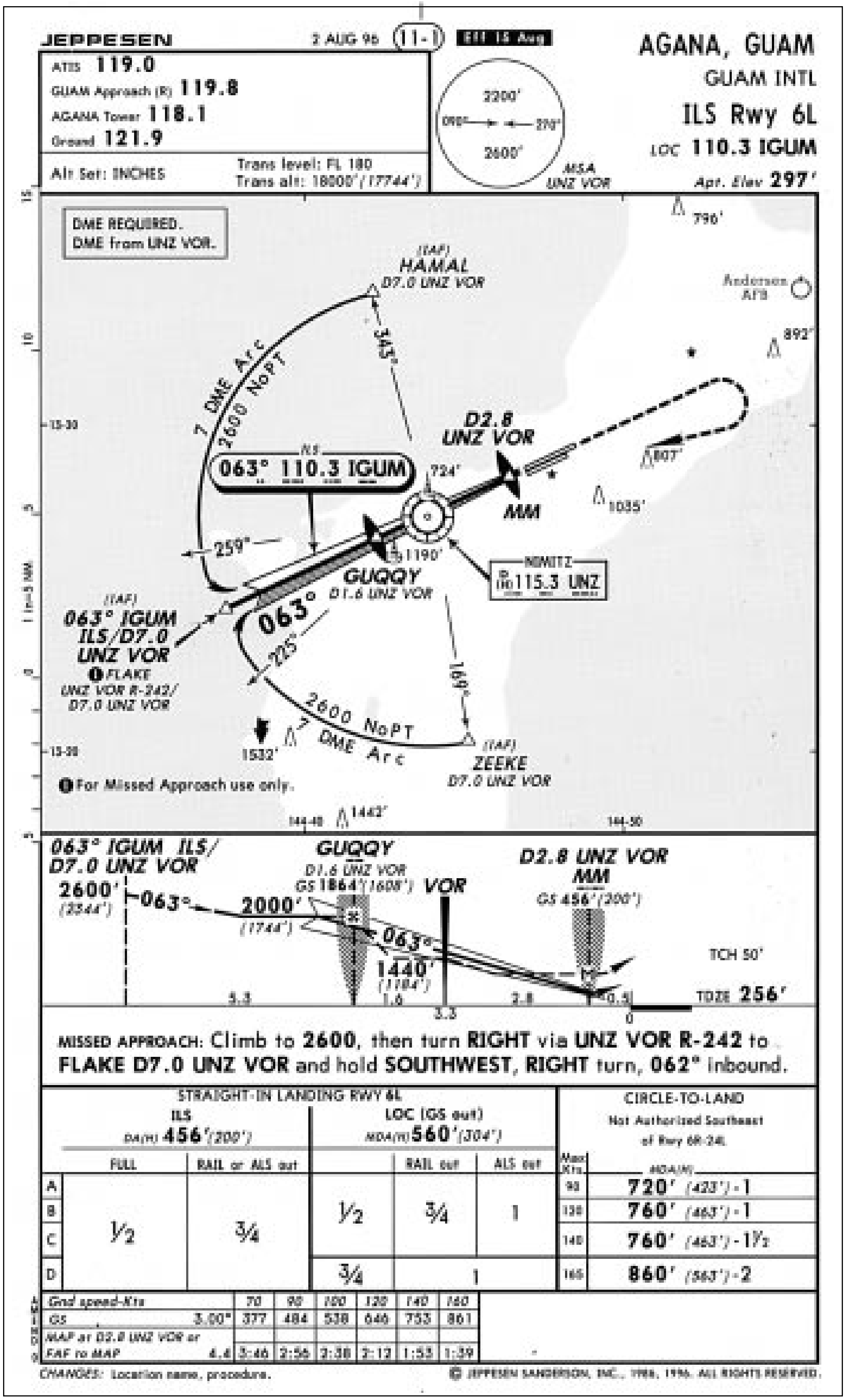
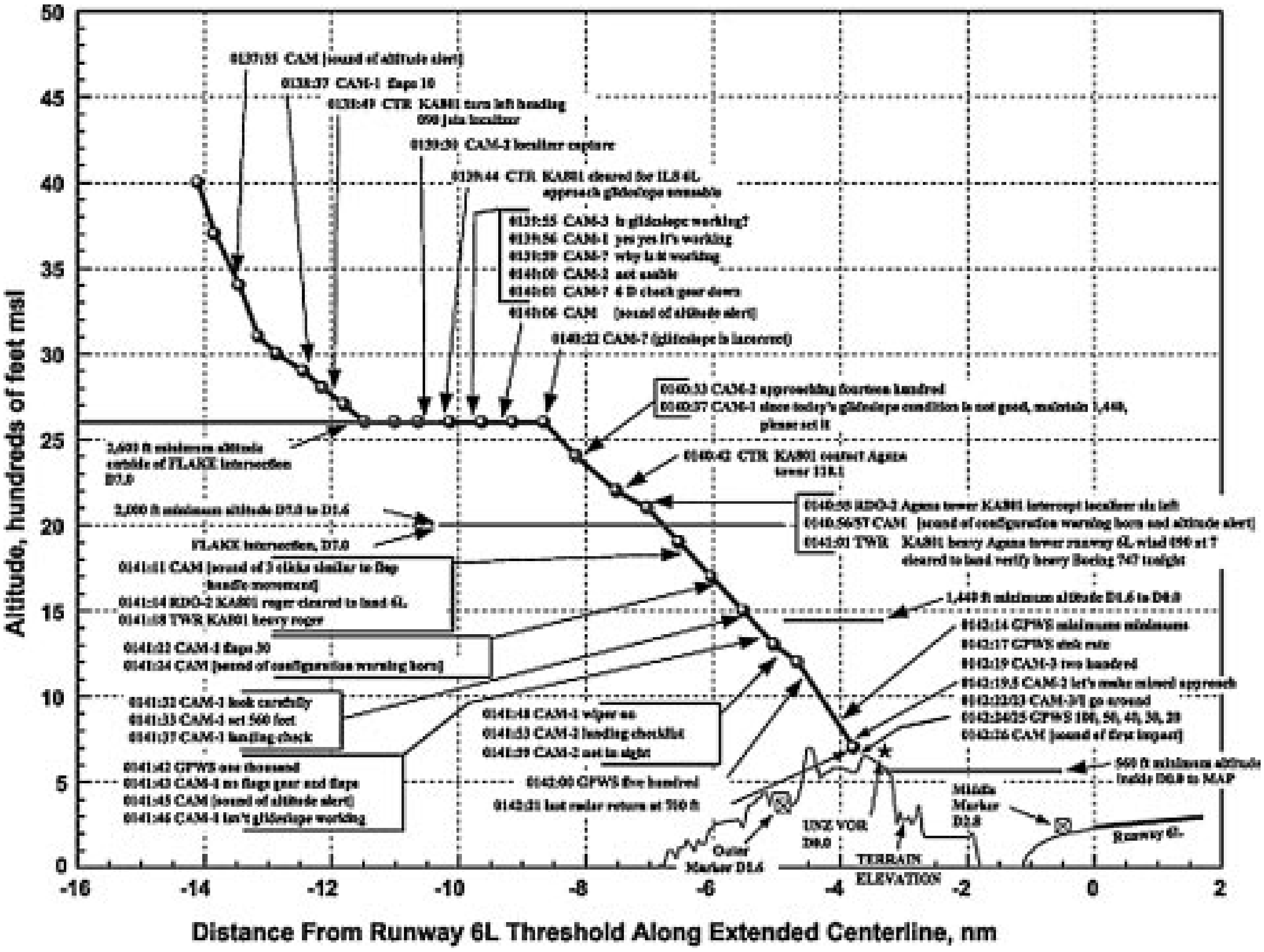


Figure 1. Instrument approach chart for the Guam International Airport runway 6L ILS procedure.

Reproduced with the permission of Jeppesen Sanderson, Inc. NOT TO BE USED FOR NAVIGATION.



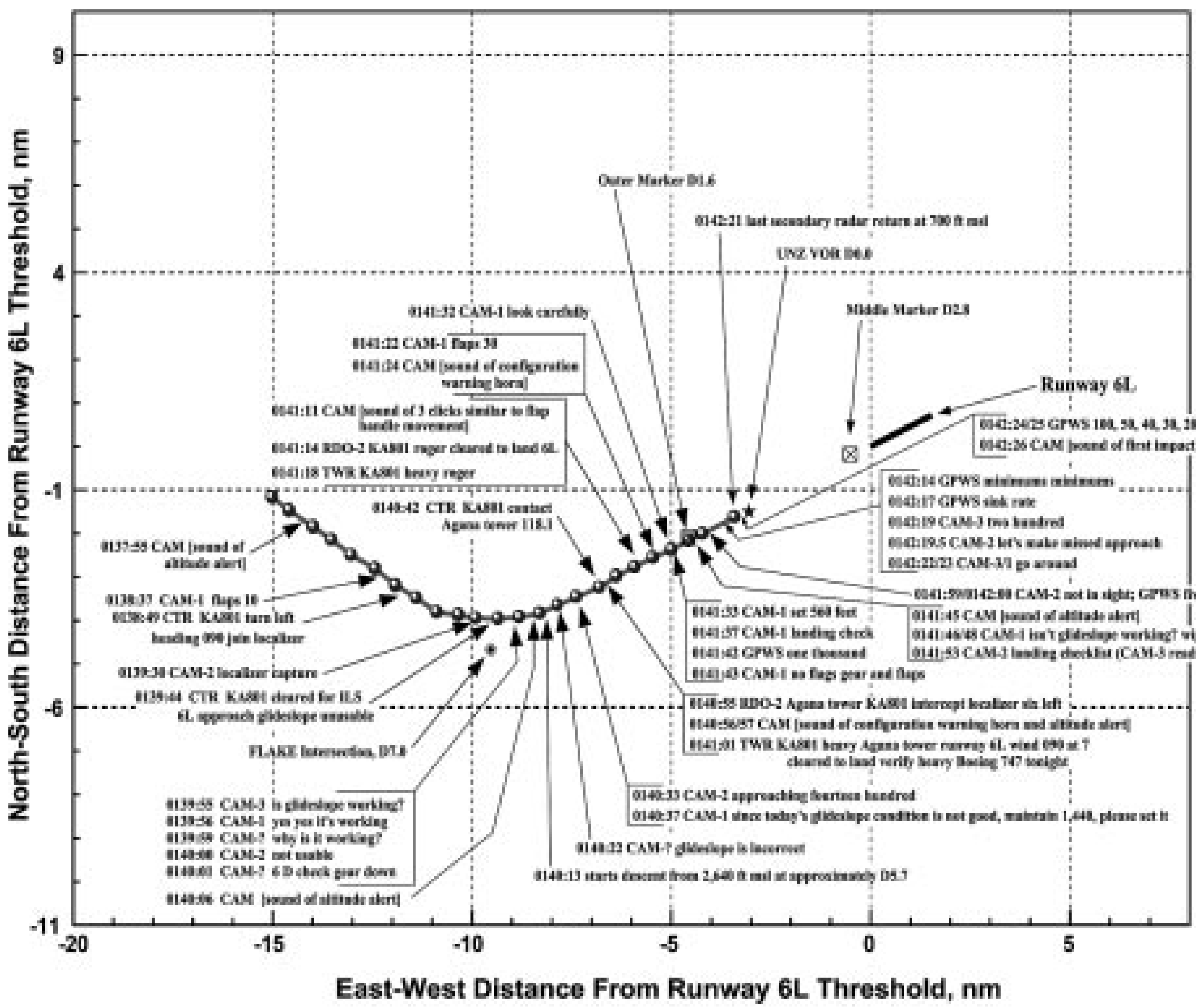
Note: Only selected CVR excerpts are shown. Appendix B contains a complete record of all CVR information and a legend of ATC abbreviations.

Figure 2. Side view of FAA radar data with selected ATC and CVR communication excerpts.

Seoul to Guam eight times as a 727 captain. In addition, he had flown from Seoul to Guam as a 747 captain on July 4, 1997 (about 1 month before the accident). National Transportation Safety Board investigators interviewed the first officer from the July 4, 1997, flight. That first officer stated that the captain had contacted him by telephone 1 day before the trip and proposed that they obtain a charter briefing for Guam because they did not regularly conduct 747 operations at that airport. Consequently, the captain and first officer arrived several hours before the trip departure time and received a charter briefing from a Korean Air instructor, even though the briefing was not required. The captain and first officer watched the Guam airport familiarization video presentation[23] and studied the approach charts for the airport. During that time, the captain commented that the area where the NIMITZ VOR is located was mountainous and required extra attention (referring to this area as a "black hole"). The first officer said the trip to Guam was routine and that the weather was good, with scattered [* cumulus] clouds and good visibility at the airport. Further, the first officer said that the captain briefed and executed the ILS 6L approach to a routine landing.[24]

The captain's last route check was on a round trip flight from Seoul to Narita, Japan, on July 19, 1997. A company check airman told Safety Board investigators that, although the weather conditions at Narita and Seoul were above instrument approach minimums, the captain executed the full ILS approach to each airport and received an "above standard" evaluation for the flights. The captain's last proficiency check was conducted in a Korean Air 747 simulator on June 11, 1997. According to Korean Air, the captain executed a nonprecision VOR/DME approach to runway 32L at Kimpo Airport during the proficiency check. The simulated weather conditions for the approach were 900 feet overcast and winds 290° at 11 knots. The captain received an "excellent" evaluation. A Korean Air representative told Safety Board investigators that the captain had passed the company's Level 3 Pilot English Test[25] and had attended crew resource management (CRM) training from October 24 to 27, 1989. The captain had not flown with the flight 801 first officer before the accident flight.

Korean Air records indicated that the captain flew a round trip flight sequence from Seoul to San Francisco, California, from



Note: Only selected CVR excerpts are shown. Appendix B contains a complete record of all CVR information and a legend of ATC abbreviations.

Figure 3. Overhead view of FAA radar data with selected ATC and CVR communication excerpts.

July 28 to July 30, 1997. He was off-duty until August 2, when he flew two round trip domestic flights between the hours of 1100 and 2000.[26] On August 3, the captain flew an international trip to Hong Kong that arrived in the early evening. The return flight was delayed because of inclement weather. The captain remained in Hong Kong overnight and flew back to Seoul the next morning, arriving about 1230.

After the accident, the captain's wife told Safety Board investigators, through a family representative, that the captain normally awoke between 0600 and 0630 and went to bed between 2200 and 2300. She stated that, on August 2, the captain awoke between 0600 and 0630 and went to bed about 2300. On August 3, the captain awoke about 0630 for the trip to Hong Kong and remained there overnight. The captain's wife stated that, after arriving home on August 4 from the trip, he was involved in routine activities and went to bed at his accustomed time. According to the captain's wife, on August 5, he awoke at 0600, worked out in a gym for an hour and returned home for breakfast. He later studied the flight schedule for the trip to Guam, took a nap from 1100 to 1340, and then ate lunch. She also stated that the captain departed for the 20-minute drive to Kimpo Airport about 1500 and that the captain had left early to allow time to prepare for the flight to Guam.

1.5.2 The First Officer

The first officer, age 40, was hired by Korean Air on January 10, 1994. He was previously a pilot in the Republic of Korea Air Force. He held an ATP certificate issued by the FAA on July 10, 1994, and a Korean ATP certificate issued by the MOCT on March 28, 1997. He received a 747 type rating on March 11, 1995, and qualified as a 747 first officer on July 23, 1995. The first officer held Korean and FAA First Class Airman Medical certificates, both issued on June 13, 1997, with no limitations.

According to company records, the first officer had accumulated a total of 4,066 hours of flight time, 2,276 hours as a military pilot and 1,790 hours as a civilian pilot. He had logged a total of 1,560 hours as a 747 first officer. The first officer had flown 189, 132, 67, and 20 hours in the last 90, 60, 30, and 7 days, respectively, before the accident. The first officer had flown from Seoul to Guam in August and September 1995 as a 747 first officer. According to company records, he viewed the Guam airport familiarization video on July 8, 1997, in preparation for a future flight to Guam.

The first officer's last route check was conducted in July 1995. The first officer's last proficiency check was conducted in a Korean Air 747 simulator on March 28, 1997. During the proficiency check, the first officer executed a nonprecision VOR/DME approach to runway 32L at Kimpo Airport. The simulated weather conditions for the approach were clouds 900 feet broken and winds 260° at 11 knots. An instructor noted, in an overall simulator session evaluation, that the first officer's "control skills and knowledge [were] above standard." The first officer received a "standard" evaluation for his nonprecision VOR approaches. However, the instructor noted that the "altitude management on nonprecision approach [was] somewhat less than desirable." Another instructor noted that the first officer was "somewhat slow to carry out directions." According to Korean Air records, the first officer had passed the Level 3 Pilot English Test but had not attended CRM training.

Korean Air records indicated that the first officer returned from an international trip to the United States on the afternoon of August 2, 1997. He was off-duty on August 3 and flew a round trip domestic flight on August 4, 1997, between 0930 and 1245. The first officer was then off-duty until the accident flight. Safety Board investigators interviewed the first officer's relatives after the accident. They stated that he telephoned his mother about 1700 on August 5 and that "everything seemed routine." Because his family lived in New Zealand, the first officer's relatives could not be specific about his activities before the accident flight.

1.5.3 The Flight Engineer

The flight engineer, age 57, was hired by Korean Air on May 7, 1979. He was previously a navigator in the Republic of Korea Air Force. He obtained his flight engineer's certificate on December 29, 1979, and was qualified on the Boeing 727 and 747 and Airbus A300 airplanes. The flight engineer held a Korean First Class Airman Medical Certificate issued on June 5, 1997. According to company records, the flight engineer had accumulated a total of 13,065 hours of flight time, including 11,088 hours as a flight engineer (1,573 hours of which were as a flight engineer on the 747). Korean Air records also indicated that the flight engineer had flown 165, 120, 77, and 28 hours in the last 90, 60, 30, and 7 days, respectively, before the accident.

The flight engineer's last two route checks were in April 1997. He received an "above standard" evaluation for the first route check and an "excellent" evaluation for the second route check. The flight engineer's last proficiency check was in a Korean Air 747 simulator on March 7, 1997. He received an "above standard" evaluation for the session, and an instructor note stated, "control skills and knowledge are above standard." The flight engineer's crew coordination was also rated as "above standard." According to Korean Air records, the flight engineer passed the Level 3 Pilot English Test and attended CRM training from April 28 to May 1, 1987. A Korean Air official indicated that the flight engineer had never flown to Guam.

The flight engineer had returned to Seoul on August 3, 1997, after completing a 3-day international trip to Anchorage, Alaska, and San Francisco. Although he was off-duty on August 4 and was assumed to have engaged in routine activities at home, the flight engineer's wife and son could not provide Safety Board investigators with details of his activities or sleep patterns before the accident flight.

1.5.4 The Flight Attendants

Fourteen flight attendants were working on the accident flight. The lead flight attendant (or purser), age 37, had been hired by Korean Air on July 18, 1988. According to company records, the purser had completed her basic training on August 28, 1988, and her most recent recurrent training was completed on December 10, 1996.

One flight attendant, age 43, was hired by Korean Air in August 1981; the other 12 flight attendants, ranging in age from 21 to 25, were hired between November 1992 and March 1997. According to company records, all had completed their basic training, and their most recent recurrent training was completed between June 1996 and April 1997.

1.5.5 The Air Traffic Controllers

1.5.5.1 Combined Center/Radar Approach Control

The CERAP controller, age 39, was hired by the FAA on May 30, 1982, in Los Angeles, California, and initially qualified as a terminal radar approach control (TRACON) controller. He transferred to the Guam CERAP facility on September 3, 1995,[27] where he was certified as a full-performance level controller. Before his employment with the FAA, the controller worked as a radar and tower controller in the U.S. Navy. His last duty station in the Navy was at Naval Air Station Cubi Point, Philippines, from 1978 to 1982. He was medically certified as a controller without waivers or limitations.

1.5.5.2 Air Traffic Control Tower

The Agana tower controller, age 39, was hired by Barton ATC International, Inc. — a nonfederal contract ATC service company — as an air traffic controller at the Guam Federal Control Tower on May 15, 1995.[28] According to company and FAA records, the controller was fully certified on all positions of operations in the tower, including clearance delivery, ground control, local control, and controller-in-charge. He was medically qualified for his duties and held an FAA Second Class Airman Medical Certificate issued on April 9, 1997, without waivers or limitations.

Before his employment with Barton ATC International, the controller held a similar position in the U.S. Navy from 1983 to 1992. During this time, the controller was trained and qualified in various TRACON positions, including radar approach control, arrival radar, radar final, departure radar, and precision and surveillance radar. He was assigned to the Naval Air Station Agana tower in 1989. The controller told Safety Board investigators that, at the Agana Naval tower, he was qualified in all tower positions and worked as a flight data controller, radar final controller, tower supervisor, facility watch supervisor, and radar branch chief. The controller remained on Guam after he was discharged from the Navy.

1.6 Airplane Information

The accident airplane, HL7468, serial number 22487, was one of three Boeing 747-300s in Korean Air's fleet. The airplane was delivered new to the company on December 12, 1984, and had been operated and maintained continuously by Korean Air until the accident. Every Korean-registered aircraft is subject to annual renewal of its airworthiness certificate from the Korean Civil Aviation Bureau (KCAB); this airplane's last airworthiness certificate was issued on July 7, 1997.

At the time of the accident, the airplane had accumulated about 50,105 hours total time in service and about 8,552 cycles.[29] The airplane was equipped with four Pratt & Whitney JT9D-7R4G2 engines with total times and cycles since new of 26,014 hours and 4,699 cycles (No. 1), 36,611 hours and 6,137 cycles (No. 2), 25,904 hours and 4,383 cycles (No. 3), and 33,889 hours and 5,701 cycles (No. 4). The most recent engine change before the accident was the replacement of the No. 3 engine on June 11, 1997, after a compressor surge incident.

According to Korean Air, the airplane was maintained according to the company's Continuous Maintenance Program, which was approved by the KCAB. The maintenance program comprised "A" checks performed at 350-hour intervals and "C" checks at 4,000-hour intervals. (Approximately 12 A checks are performed between each C check.) The last A check was performed on July 12, 1997, at 49,874 hours. The last C check was performed on December 16, 1996, at 47,918 hours. During the C check, operational/functional test work cards were completed for the transponders, radar altimeters, VOR/ILS navigation receivers, central air data computers, GPWS, autopilot, automatic direction finder (ADF), altitude alert, inertial navigation systems, weather radar, DME, and high-frequency radios. Further, the FDR was read out, and the altimeters were calibrated.

1.6.1 Maintenance Discrepancies Before the Accident Flight

The accident airplane's logbooks indicated that, from December 1996 (the time of the last C check) to August 1997, all mechanical discrepancies identified by flight crews or maintenance personnel had been corrected before the next scheduled flight. Several discrepancies were deferred, in accordance with Korean Air minimum equipment list guidelines, and the airplane was flown to Seoul for repair. The airplane's logbook entries during this time period detailed the following maintenance deficiencies and corrective actions:

- Between December 18, 1996, and January 5, 1997, five airspeed-related writeups were logged, including one that identified a discrepancy of up to 50 knots between the captain's and first officer's airspeed indicators while in cruise. Corrective actions were taken.

- On April 9, 1997, the GPWS failed the "below glideslope" test. Contamination was cleaned from a connector.

- Between May 3, 1997, and June 23, 1997, six writeups were logged about erroneous fuel quantity indications on the No. 1 fuel quantity indicator. The system was checked after each event.

- On July 3, 1997, the first officer's altimeter was replaced.

- On July 30, 1997, during an autocoupled approach at Seoul, autopilot channel "A" disengaged at a radar altitude of 1,000 feet. (According to a Boeing representative, because the autopilot is a triple-redundant system, it would have continued to control the airplane using the "B" and "C" channels.) A pin on one of the autopilot system's electrical connectors was subsequently cleaned.

Korean Air records indicated that the accident airplane had no deferred maintenance items when it was dispatched on August 5, 1997, and that no discrepancies had been identified in the airplane's logbook for the previous 12 flights. The partially completed logbook page for the accident flight was recovered from the wreckage, and no maintenance writeups had been logged.

1.6.2 Cockpit Instrumentation

The captain's and first officer's instrumentation panels from the Boeing 747 Classic are shown in figures 4 [* page 17] and 5 [* page 18], respectively. A discussion of the accident airplane's autopilot system, GPWS, and ILS follows.

1.6.2.1 Autopilot System

The accident airplane was equipped with a Sperry-Rand (now Rockwell Collins) autopilot, model SPZ1. The autopilot system

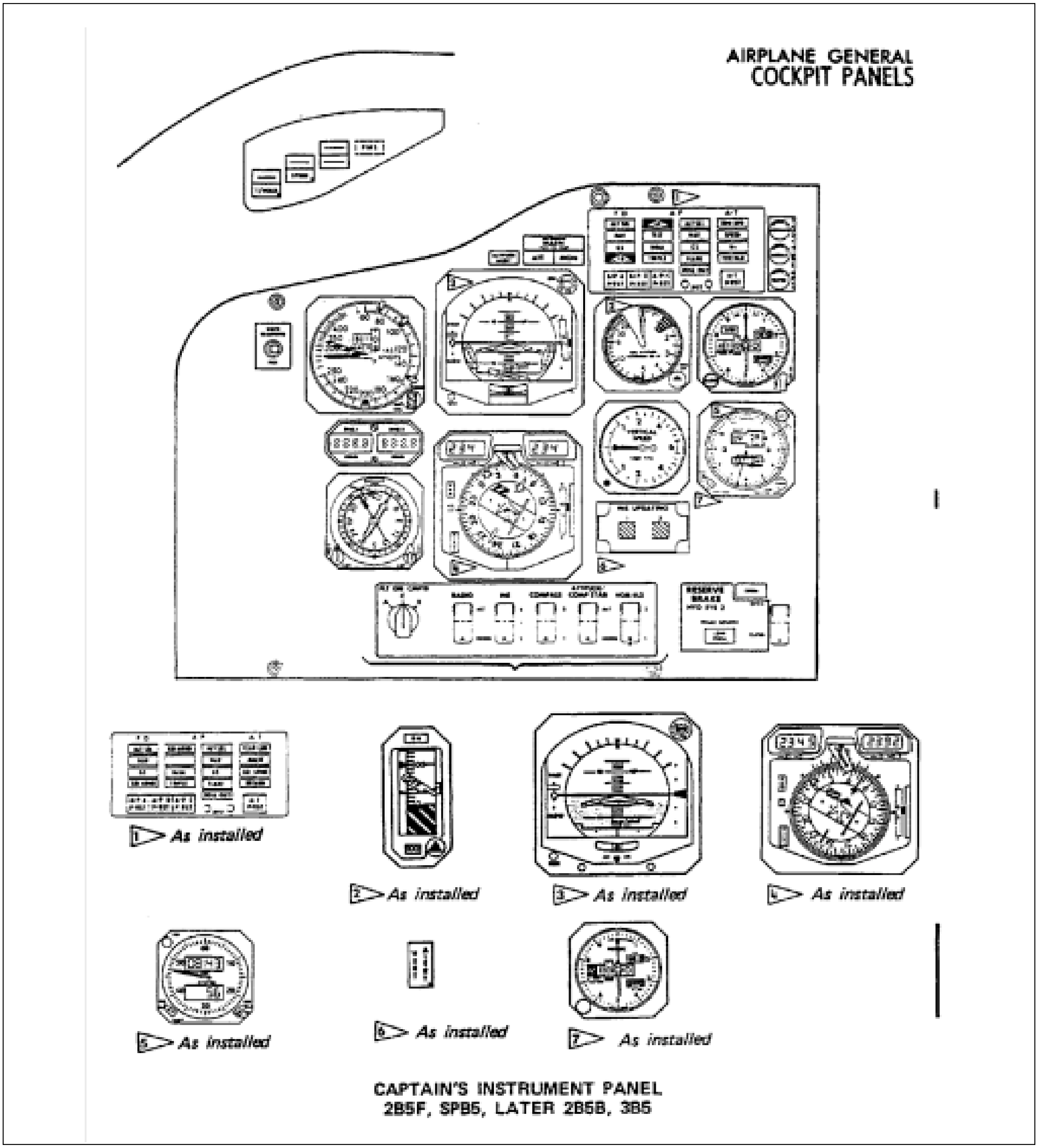


Figure 4. Captain's instrumentation panel.

Reproduction courtesy of The Boeing Company.

consists of a mode control panel and three pitch and roll computers (with a landing rollout function) that drive the pitch and roll actuators. In addition, two separate yaw damper computers provide control to the "split" rudder system (two individual rudder panels).

Boeing engineers stated that, when the autopilot's ILS mode is selected by the pilot and a sufficient glideslope signal exists, the glideslope "armed" indicator is annunciated in the cockpit with an amber light. The pitch and roll computers maintain pitch control and operate in any of the following modes:

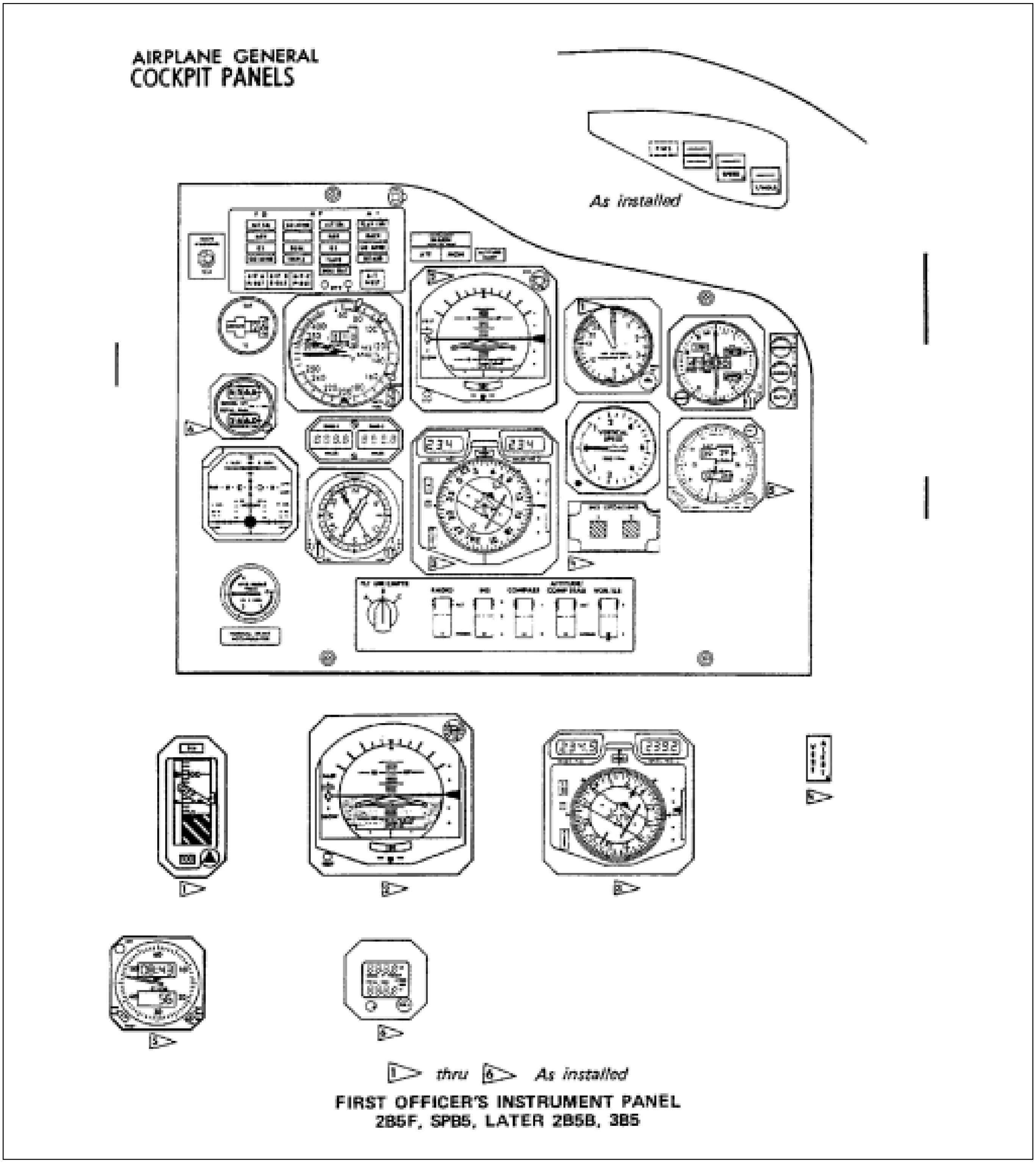


Figure 5. First officer's instrument panel.

Reproduction courtesy of The Boeing Company.

"Altitude Hold," "Altitude Select," "Indicated Airspeed Hold," or "Vertical Speed." When the deviation of the glideslope signal reaches a predetermined level, the vertical beam sensor automatically switches the landing rollout computer function to control the pitch axis of the elevator. The glideslope signal is validated before the system can arm the glideslope "engage" logic and the vertical beam sensor. According to Boeing, if the glideslope signal is invalid, the failure will be annunciated in the cockpit with a steady red "autopilot" warning light.

The altitude alert system is coupled to the autopilot. The altitude alert is armed by the pilot when the desired altitude is set into the "ALT SEL" (altitude select) window on the pilot's control panel (or glareshield). The amber "ALTITUDE ALERT" light illuminates steadily, and a 2-second aural tone sounds when the aircraft is approaching the selected altitude from either 900 feet above or below. The light remains illuminated until the aircraft is within 300 feet of the desired altitude. The light then flashes, and the 2-second aural tone sounds when the aircraft deviates 300 feet above or below the selected altitude until the deviation exceeds 900 feet, at which time the light extinguishes and the system automatically resets for subsequent altitude alerting. The "deviation from altitude" mode of the altitude alert system deactivates when the landing gear is extended.

1.6.2.2 Ground Proximity Warning System

The accident airplane was equipped with an AlliedSignal Mark VII GPWS Warning Computer.[30] The mode 2 warnings "TERRAIN" and "PULL UP" were desensitized[31] during flight 801's approach while the airplane was in the landing configuration (gear down/flaps extended). The advisories and alerts that remained active in the landing configuration were those for excessive descent rate (sink rate); excessive terrain closure rate; excessive glideslope deviation; minimums (radio altitude decision height) callout; and 1,000, 500, 100, 50, 40, 30, 20, and 10 feet radio altitude callouts.[32]

On October 3, 1997, postaccident testing of the GPWS installed on flight 801 was performed at AlliedSignal facilities in Redmond, Washington. The testing found that the GPWS was capable of normal operation.

1.6.2.3 Instrument Landing System

The accident airplane was equipped with three Rockwell International/Collins Model 51RV-5B ILS receivers. No recorded malfunctions or abnormalities with the three receivers were recorded between the time of their respective installations (from November 1996 to May 1997) and the accident.

In a normally functioning system, ILS information is displayed in the cockpit on the captain's and first officer's raw data indicators on the attitude director indicator (ADI) and the horizontal situation indicator (HSI) if they are receiving localizer and glideslope information. In addition, the ADI's flight directors (FD) display ILS information if the appropriate FD mode is selected.[33] The ADI and HSI are equipped with a warning flag that is displayed over the ILS indications (localizer and glideslope) to alert a pilot if either the ground or airborne system fails or if the receivers are not set to the correct radio frequency.[34]

According to the manufacturer, the glideslope warning flag will appear if the navigation receiver is tuned to an ILS frequency and any of the following conditions exist:

- there is an absence of a glideslope radio-frequency signal or 90- and 150-Hertz (Hz) modulations;
- the percentage of modulation of either the 90- or 150-Hz signal is reduced to zero and the other is sustained at 40 percent or more; or
- the level of a standard glideslope deviation signal produces 50 percent or less of the standard deflection of the deviation indicator.

1.6.3 Weight and Balance

The weight and balance form signed by the captain and the dispatcher for the accident flight included the following data:[35]

- zero fuel weight, 197,897 kilograms (kg);
- departure fuel, 51,847 kg;
- trip fuel, 36,923 kg;
- takeoff weight, 249,744 kg;
- estimated landing weight, 212,821 kg;
- passenger weight (including cabin baggage), 17,694 kg;
- cargo in compartments, 7,333 kg;
- takeoff weight center of gravity, 24 percent mean aerodynamic cord; and
- takeoff stabilizer trim setting, 4.4 units.

1.7 Meteorological Information

1.7.1 Weather Conditions at Guam International Airport

Guam's climate is relatively uniform throughout the year. Guam averages 247 days each year with measurable amounts of precipitation (rain), and most days begin with scattered layers of clouds that become broken to overcast by afternoon.

From August to October, visual meteorological conditions (VMC) prevail about 80 percent of the time, and instrument meteorological conditions (IMC) prevail predominately during the afternoon hours. The rainy season lasts from July to November. During that time, precipitation averages about 24 days per month, and the prevailing winds are usually from the east, averaging about 9 knots.

A weather synopsis prepared by the Guam National Weather Service (NWS) Office on the day of the accident stated:

… a weak low pressure trough is moving slowly [through] the Mariana Islands … resulting in gentle to moderate easterly winds and scattered showers. The effects of the upper level low far to the northeast have diminished during the past 12 hours or so. Light to moderate showers should be expected except for isolated afternoon thunderstorms due to solar heating.

About 0122:06 during the accident flight, the flight crew was informed by the CERAP controller that ATIS information Uniform was current. The content of that report was as follows:

Agana tower information UNIFORM, time one four five zero zulu, wind calm, visibility seven, [clouds] one thousand six hundred scattered, two thousand five hundred scattered, temperature two seven [Celsius], dew point two four, altimeter two niner eight six, runway six in use. NOTAMs [Notices to Airmen[36]], runway six left ILS glideslope out of service until further notice, advise on contact you have information UNIFORM.

The special surface weather observation for 0132 on August 6, 1997, was as follows:

Wind 090° at 6 knots; visibility — 7 miles; present weather — shower vicinity; sky condition — scattered 1,600 feet, broken 2,500 feet, overcast 5,000 feet;[37] temperature — 27° C; dew point — 25° C; altimeter setting 29.85 inches Hg; remarks — showers vicinity northwest-northeast.

The special surface weather observation for Guam International Airport for 0147 on August 6 was as follows:

Wind variable at 4 knots; visibility — 5 miles; present weather — light rain shower; sky condition — few 1,500 feet, scattered 2,500 feet, overcast 4,000 feet; temperature 26° C; dew point 24° C; altimeter 29.85 inches Hg.

The Safety Board examined the NWS surface weather observation logs and found that heavy rain showers were reported at the airport between 0020 and 0029, between 0114 and 0116, and between 0153 and 0158. The weather logs also indicated that light rain showers were reported at the airport between 0016 and 0020, between 0029 and 0033, between 0106 and 0114, between 0116 and 0128, and between 0138 and 0148. Further, light rain and mist were also reported between 0148 and 0153. The maximum windspeed recorded at the airport between 0130 and 0150 was about 10 knots.

The following terminal aerodrome forecast (TAF) for Guam International Airport, which was issued by the NWS on August 6 at 0030 as an amendment to an earlier TAF, was valid at the time of the accident:

Wind 120° at 7 knots, visibility greater than 6 miles, scattered 1,600 feet scattered 4,000 feet scattered 8,000 feet overcast 30,000 feet. Temporary August 6, 0100 to August 6, 0600, wind 130° at 12 knots gusting 20 knots, visibility 3 miles, heavy rain shower, broken 1,500 feet cumulonimbus overcast 4,000 feet.

The radar antenna of the Guam Weather Surveillance Radar-1988, Doppler (WSR-88D) was located about 5 nm east of the accident site. Data recorded about 0143 on August 6 (1543 UTC time on August 5, 1997) indicated an area of precipitation over higher terrain about 4 nm southwest of the airport, including Nimitz Hill. The precipitation was oriented east to west, about 7 to 8 nm long and 3 to 4 nm wide, and was moving toward the west. Figure 6 [* page 21] shows the WSR-88D four-panel base reflectivity product for 0143.

1.7.2 Air Traffic Control Weather Information

The CERAP radar controller stated that, although areas of weather were in the vicinity of the VOR and airport, he had not received any pilot reports from midnight to the time of the accident. The controller stated that a "relatively small cell,"[38] which he believed to be of light to moderate intensity, was depicted on the Airport Surveillance Radar (ASR)-8 display. Further, the controller said that the "relatively small cell" observed on radar extended about 3 to 5 miles on the final approach course and was about 2 to 3 miles across in the largest area. The controller said that he had no means of determining the intensity of this or any other weather cell because, unlike other weather radar displays, the ASR-8 radar display is monochromatic, and it is difficult to differentiate precipitation intensity without color. However, the controller also said that he interpreted the intensity of precipitation by the different levels of opaque (white) shading and his experience as a controller.

The CERAP controller stated that he did not advise the flight crew or the Agana tower controller that he had observed the precipitation on radar while flight 801 was on the approach course to the airport. The controller said that he had assumed that the flight crew was using cockpit radar because they had asked him twice for deviations around weather. The controller stated that the airplane's cockpit radar was more accurate and more precise than the radar he was using at the CERAP. The controller further stated that he did not observe (on radar) the airplane entering the precipitation.

FAA Order 7110.65, "Air Traffic Control," paragraph 2-6-4 (a) states that a controller is to "issue pertinent information on observed/reported weather or chaff[39] areas. Provide radar navigational guidance and/or approved deviations around weather or chaff when requested by the pilot … ." Paragraph 2-6-4 (c) states that a controller is to "inform any tower for which you provide approach control services if you have any weather echoes on radar which might affect their operations." Further, paragraph 2-9-2 states that, in the event of "rapidly changing conditions," a new ATIS is to be recorded and that the information is to be issued by ATC.

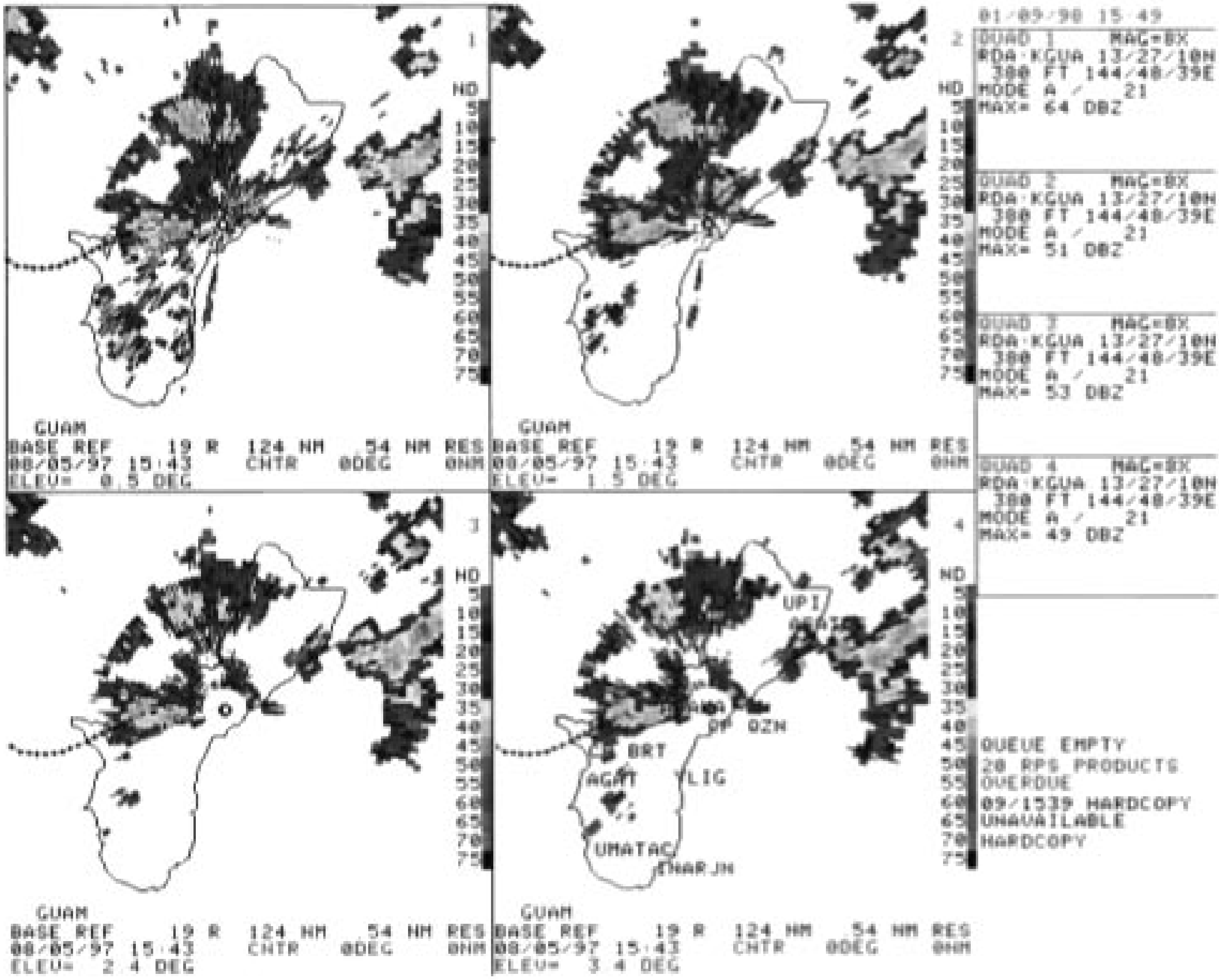


Figure 6. USR-88D four-panel base reflectivity product for Guam.

The Agana tower controller stated that, although it was not raining at the airport when flight 801 was inbound, a rain shower was moving in from the northeast over the airport and down the runway to the southwest. The tower controller said that he did not know when the rain began at the airport because he was using binoculars to try to locate flight 801 on the approach. He estimated that the visibility was 7 miles and stated that no low clouds were visible.

1.7.3 Additional Weather Information

A certified Navy weather observer on Nimitz Hill, about 3/4 mile northwest from the accident site, stated that the cloud ceiling about the time of the accident was approximately 700 to 800 feet above ground level (agl), or 1,300 to 1,400 feet msl, during a heavy rain shower. Also, he stated that visibility was about 200 to 300 meters and that the windspeed was not more than 10 knots. The NWS forecaster on duty at the time of the accident stated that no SIGMETs [Significant Meteorological Information] were valid for Guam and that the night was "pretty routine."

The flight crew of Continental Air Micronesia flight 960, a Boeing 747 that landed at Guam about 30 minutes before the accident, stated that visibility was "excellent" from PAYEE intersection (located about 240 nm north of the NIMITZ VOR) and that scattered thunderstorms were occurring around the area. Further, the pilots indicated that their on-board radar depicted rain showers over the NIMITZ VOR but not over the airport. They also stated the visibility was "good" under 2,000 feet and that they maintained visual contact with the airport throughout the approach.

The flight crew of Ryan International flight 789, which landed shortly after the accident occurred, stated that the visibility was sufficient to see the lights of Guam from about 150 nm away. The first officer stated that on-board weather radar indicated showers northeast of the airport but no thunderstorms.

Additionally, the Ryan flight crew initially requested a visual approach when the flight was about 15 nm from the VOR, but the airplane encountered clouds and rain on approach to runway 6L shortly thereafter. The first officer stated that the airplane remained in the clouds until it was in proximity of the VOR, at which time the airplane broke out and the flight crew was able to acquire and maintain visual contact with the airport. The captain stated that, although clouds and rain were over the island's shoreline, the air around the airport and in the vicinity of the accident site was smooth. Further, the captain, who was also a check airman based at Guam, said that he "noticed that once [flight] crews are given a visual approach [to Guam International Airport] they have a tendency to press on even when they lose visual contact in hopes of regaining visual contact again … . That's because so many approaches are visual and the clouds and rain showers are so localized."

In addition, a witness who was hunting on Nimitz Hill at the time of the accident stated that it was not raining when he observed flight 801 pass over his position (100 feet north of the VOR beacon) and crash a very short distance away. He said that there had been intermittent rain showers shortly before the accident but that, when he saw the airplane crash, he could see stars directly over the accident site. The witness also said that the visibility was "very good" at the time of the accident and that, although he could not see the airport lights, he could see the lights of the town of Tamuning (3 to 4 miles northeast of his location). He said that the wind was "normal" and that no thunder or lightning was in the area.

1.8 Aids to Navigation

Guam International Airport is serviced by three navigational aids: the NIMITZ VOR/DME (UNZ); the Mount Macajna nondirectional beacon (NDB), which was not operational at the time of the accident; and the ILS glideslope and localizer.

The colocated VOR and DME transmitters were equipped with a "self-monitoring" system that samples radiated transmitter signals to ensure that the system is operating within prescribed tolerances and parameters. If these tolerances are exceeded, the monitoring system automatically shuts down the equipment. According to the facility logs, the VOR was not shut down at the time of the accident.

On the day of the accident, the FAA conducted a flight check of the localizer, outer marker, and NDB at Guam. The VOR and DME at Guam were not checked by the FAA until the day after the accident because of rescue operations. The FAA's flight checks determined that the respective systems were functioning properly and within prescribed tolerances.[40] The flight checks did not examine the glideslope because it was out of service and removed at the time (see section 1.10.2 for more information).

1.9 Communications

No communications problems were reported between the crew of flight 801 and any of the FAA or contract ATC facilities. (See sections 1.7.2 and 1.10.1 for more information.)

1.10 Airport Information

The A.B. Won Pat Guam International Airport is located about 3 nm northeast of Agana on the west-central coast of Guam at an elevation of 297 feet msl. The airport is leased to the Guam International Airport Authority by the U.S. Navy, and the associated navigational facilities are owned and operated by the FAA. The airport has two parallel runways oriented northeast/southwest: runway 6R/24L, which is 8,001 feet long and 150 feet wide, and runway 6L/24R, which is 10,015 feet long and 150 feet wide.

Runway 6L is equipped with high-intensity runway edge lights and a medium-intensity approach lighting system with runway alignment indicator lights.[41] The runway was not equipped with runway end identifier lights, centerline lights, or touchdown zone lights. Runway 6L is also equipped with a four-box visual approach slope indicator (VASI) calibrated for a 3° visual glidepath angle. The touchdown elevation of runway 6L is 256 feet but rises to 297 feet at the departure end of the runway.

Guam International Airport was certified by the FAA as an Index D aircraft rescue and firefighting (ARFF) facility under 14 CFR Part 139. In accordance with this index, the airport is required to maintain a minimum of three ARFF vehicles capable of carrying a total quantity of at least 4,000 gallons of water.

1.10.1 Air Traffic Control Services for Guam International Airport

1.10.1.1 Combined Center/Radar Approach Control

The Guam CERAP, located at Andersen Air Force Base (AFB),[42] provides both TRACON and en route ATC services. To do so, the CERAP is equipped with two independent radar data processing systems that receive radar information from different radar sites: terminal ATC services are provided by an Automated Radar Terminal System (ARTS) IIA analog display processor connected to an ASR-8 radar system; en route ATC services are provided by a digitized, narrow-band Micro-En route Automated Radar Tracking System (EARTS) processor connected to an FPS-93 long-range radar.[43] Each of these systems independently performs its own minimum safe altitude warning (MSAW) processing (see section 1.10.1.2) but uses different algorithms that have been optimized for either terminal or en route operations. Both the FPS-93 and ASR-8 sensors are located about 1,500 feet apart on Mount Santa Rosa.

The CERAP airspace comprises concentric circles centered around the Mount Santa Rosa radar antenna site. The 250-nm-radius outer ring, which encompasses all of the airspace from above the surface, is classified as oceanic airspace. A 100-nm-radius inner ring, which extends over the Saipan radio beacon and from the surface to 28,000 feet, is classified as domestic airspace.[44] The CERAP airspace is adjoined on all sides by the Oakland Air Route Traffic Control Center oceanic sectors. The airspace over Saipan and Guam is classified as approach control airspace, and its boundaries extend from the surface to 17,000 feet. The CERAP was classified as a Level II facility at the time of the accident.[45]

The CERAP facility has two en route and one approach control radar positions. The R-1 en route radar position is responsible for the 100-nm inner circle; the R-4 en route radar position is responsible for the 250-nm outer circle. The D-3 approach control radar position, which is located between the en route R-1 and R-4 radar positions, is responsible for a 25-nm inner ring that extends from the surface to 17,000 feet and includes the NIMITZ VOR and the Andersen TACAN.[46] At the time of the accident, one controller was performing the functions of all three positions from the R-4 position.

Authorized staffing for the Guam CERAP comprises 14 full-performance level controllers, 3 supervisors, an Automation Specialist, a Quality Assurance/Training Specialist, an Air Traffic Manager, and a secretary. According to FAA quality assurance staff at Guam, afternoon traffic at Guam is primarily overflights of aircraft traveling northbound, and evening traffic is primarily aircraft traveling inbound from Asia.

The CERAP controller on duty at the time of the accident told Safety Board investigators that, after arriving at the facility at 2345 on August 5, 1997, he assumed the duties at the R-4 en route radar position (and the colocated R-1 en route and D-3 approach control radar positions). A coworker arrived at the facility and assumed the duties at the D-3 position from midnight to 0110, at which time he went on a break. The controller then resumed the duties of the D-3 position. (His coworker was not in the control room at the time of the accident.)

The CERAP controller stated that he was monitoring the EARTS (en route) radar display, which was set to 265 nm (but normally covers 250 nm). The controller also said that the en route radar display (which was located directly in front of him) was set to show the MSAW area in the lower right corner. (Controllers are able to set radar information to any position on the radar screen.) According to the controller, the en route radar system was displaying only secondary radar (beacon) target information[47] throughout his shift. (The system was set up that way when he relieved the previous controller on duty.) He said the en route radar system was not able to display weather information because the part of the system that would normally display such information was out of service.

Further, the CERAP controller told investigators that the TRACON radar display (which was located to his immediate right) was set to a 60-nm range. The controller also stated that the approach control radar was set to display the MSAW area in the lower center of the screen. In addition, the controller said that the approach control radar was displaying primary and secondary radar return targets[48] and areas of weather that were moving through the Guam area throughout his shift.

The CERAP controller also told investigators that the traffic complexity and density, that is, the number of aircraft under his control, from the time of initial radio contact with flight 801 (about 0103:18) to the time he advised the flight crew to contact the Agana tower (about 0140:42) was "light to moderate traffic and routine complexity." The controller estimated that he was handling 10 to 15 aircraft during that time, including flight 801.

After the CERAP controller initiated the communications change (instructing flight 801 to contact the Agana tower controller), he was still responsible for radar monitoring of the flight because the Agana tower was a VFR facility and none of the criteria for automatic termination of radar service, as stated in FAA Order 7110.65, "Air Traffic Control," paragraph 5-1-13, had been met. However, the CERAP controller was no longer able to directly contact the airplane after it had switched to the Agana tower frequency.

During a postaccident interview, the controller stated that he did not monitor the progress of flight 801 after the communications changeover because he was performing other duties that might have precluded further monitoring. According to the transcript from the recorded voice communications of radio and interphone lines during the period that flight 801 was in communication with the Agana tower, the CERAP controller made a radio transmission to another aircraft about 0140:54. From about 0141:14 to 0141:30, he was on the interphone with a controller at the Oakland Center. About 0142:05, the CERAP controller acknowledged a transmission from the flight crew of Ryan International flight 789. The transcript indicated no further activity until about 0143:49, when the CERAP controller called the Agana tower with a flight plan. The CERAP controller said that he last observed the target of flight 801 on the terminal radar display when the airplane was 7 miles from the airport at an altitude of 2,600 feet.

Between 0150 and 0151, the CERAP controller was queried by the Agana tower controller about flight 801. About 0154:44, the CERAP controller contacted Ryan flight 789 and stated, "ryan seven eighty nine roger we may have lost an airplane … ." About 0156:03, the CERAP controller requested the Ryan flight crew to " … look for signs of an accident west of the airport." About 0156:35, a Ryan flight crewmember advised the CERAP controller, " … about fifteen minutes ago we saw the clouds light up bright red it was kinda weird we thought it was just our eyes or something." About 0156:58, the crewmember advised the controller, "we got a big fireball on the hillside up here … about our three o'clock and two miles — ah a mile."

1.10.1.2 Minimum Safe Altitude Warning System

Beginning in 1977, MSAW functions were incorporated into the ARTS software installed in FAA terminal radar data processing systems.[49] According to FAA technical document NAS-MD-684, MSAW provides general terrain monitoring for all aircraft, including those not on approach, within a predetermined geographic area and approach path monitoring for certain aircraft operating within an approach capture box (a rectangular area surrounding a runway and final approach course). The document also states that aircraft on approach are to be monitored based on their current or predicted altitude compared with the lowest MDA for the approach and that warning alerts are based on an "aircraft's relative position to a runway threshold and final approach course centerline."

The ARTS IIA MSAW system uses computer software that contains a terrain database customized for the environment around each airport that utilizes ARTS processors. The MSAW system is designed to visually and aurally alert a controller whenever an IFR-tracked target with an altitude encoding transponder (Mode C) descends below, or is predicted by the software to descend below, a predetermined safe altitude. The ARTS IIA and EARTS MSAW systems use approach capture boxes aligned with runway final approach courses to identify aircraft that are landing. Within these boxes, MSAW applies special rules specific to approach and landing operations. The ARTS IIA adaptation allows the use of a "pseudo-glideslope" that underlies the actual glideslope. Predicted or actual descent below this pseudo-glideslope normally produces a low-altitude alert. EARTS approach adaptation is less sophisticated and does not include glideslope monitoring; instead, a single base altitude is used for the entire approach capture box.

According to FAA records, the Guam terminal (approach) MSAW system was originally installed in 1990 to provide altitude protection within a 55-nm radius around the Guam ASR-8 site. In March 1993, a new software package was developed and evaluated by FAA technicians for installation at Guam. The new software was designed to inhibit MSAW alerts inside a 54-nm radius of the Guam ASR-8 site. Thus, the MSAW was only available (uninhibited) for a 1-mile radius (from 54 to 55 nm around the Guam ASR-8 site). According to FAA representatives, this change, designed as a temporary solution to reduce false, or "nuisance," warnings, was submitted by the Guam CERAP and approved by the FAA's Western Pacific Regional Office. The Safety Board requested documentation of the reasons for the changes, but the FAA was unable to explain the specific reason(s) for the change in the MSAW configuration.[50] The FAA Technical Center in Atlantic City, New Jersey, modified the software and delivered it to Guam in January 1994, but the software did not become operational until February 1995. (The EARTS MSAW system at Guam only generates visual MSAW alerts, and these alerts were not inhibited at the time of the accident.)

The ARTS IIA system recorded no alerts for Korean Air flight 801 at any time. The EARTS MSAW alert records showed that a visual approach path warning was generated at 0142:20, about 6 seconds before the crash of flight 801, and continued until at least 0142:49.

At the Safety Board's public hearing,[51] the FAA's Deputy Program Director of Air Traffic Operations testified that, in some circumstances, controller issuance of an MSAW-based safety alert could be a first-priority duty equal to separation of aircraft. FAA Technical Center management testified that MSAW is a safety-critical service.

An FAA quality assurance evaluation report, dated July 31, 1995, on the Guam CERAP facility stated that the MSAW system had been inhibited and that a NOTAM had been issued about the inhibited MSAW.[52] An FAA representative stated that, because no "established policy" existed for MSAW operations at the time of the 1995 evaluation, the MSAW inhibition was noted only as an "informational" item in the evaluation team's report and, as a result, did not require corrective or follow-up action. The report also indicated that a new digital terrain map had been ordered and was scheduled for delivery in April 1995 but that the delivery date had been rescheduled for August 1995.

FAA documents revealed that new MSAW software became operational in April 1996, but it contained the same 54-nm-radius inhibition as the February 1995 version. About 1 year after the installation of the new software, the FAA conducted another facility quality assurance evaluation of the Guam CERAP. The evaluation report, dated April 1997, did not note that the ARTS IIA MSAW system remained inhibited.

According to the FAA, the MSAW system at Guam was restored to full, uninhibited operation on August 23, 1997 (17 days after the flight 801 accident), after the monitoring software parameters were adjusted to reduce false alert incidents.[53] The FAA indicated that, since that time, controllers had been experiencing about 18 nuisance alarms per day and that work was ongoing to reduce these alarms.

1.10.1.3 Air Traffic Control Tower

The Agana tower is responsible for operations within the surrounding Class D airspace, which is defined as the airspace within a 5-statute mile radius from the center of the Guam International Airport up to, but not including, 2,500 feet agl. The tower facility is located on the south-southwest side of the airport and is operational 24 hours a day. The controller positions are arranged in a semicircular pattern that face generally from the southwest to the northeast. The four operational positions are the controller-in-charge, local control, ground control, and flight data. All of the positions are typically worked by one controller as a combined function, but the positions may be separated depending on traffic conditions and staffing levels.

In August 1994, Barton ATC International, Inc., was awarded the contract to provide ATC services at the Agana tower. Barton was purchased by Serco Aviation Services, Inc., in January 1997. According to a Serco official, 6 controllers with an average of 15 years of experience worked at the tower at the time of the accident.[54] Three of these staff members, including the Air Traffic Manager, had worked at the facility when it was operated by the U.S. Navy.

The Guam Air Traffic Manager said that the FAA evaluated the tower facility at Guam in October 1995 to determine whether a new tower should be constructed or the existing facility should be upgraded. The FAA also evaluated the Guam tower in September 1996, and the Air Traffic Manager learned that the facility would be upgraded with digital bright radar indicator tower equipment (D-BRITE) [55] displays.

In February 1997, two D-BRITE systems were delivered to the Agana tower, and the radar displays were installed by the FAA in July 1997. The tower controller on duty at the time of the accident stated that the D-BRITE radar display was operational but had not been certified for use. (At the time of the accident, the associated control panels for configuring the Guam tower D-BRITE video maps and settings were located at the Andersen AFB tower. According to the FAA, the equipment at the Agana tower was not certified or commissioned for use because of missing hardware and computer software.) The tower controller stated that the display showed secondary radar targets but that the radar setting selected by the Andersen AFB controllers determined whether Mode C targets would be displayed. He said that the controllers at Guam were not able to determine an airplane's position on the video map because it did not depict any final approach courses or runway orientations for the airport.

By December 1997, the two D-BRITE systems had been tested, and the Agana tower controllers received training on the systems' operation. The D-BRITE systems were certified and commissioned for use on April 11, 1998. The video map has been modified to depict the airport with extended centerlines for both runways 6L and 6R, and the system is controlled at the Guam tower.

The Agana tower controller on duty at the time of the accident told Safety Board investigators that he arrived for duty about 2215 on August 5, 1997. After that time, he and the controller on duty performed a position relief briefing, which covered airport conditions, navigation aid conditions, traffic clearances that had been issued, and the facility equipment status. After midnight, the controller performed daily administrative duties. The controller said that he was working at the local control position, which was located in the center of the tower cab facing the runway. The controller also stated that he was aware of the NOTAM regarding the out-of-service glideslope.

The tower controller said that, when Korean Air flight 801 made initial radio contact (about 0140:55), it was the only airplane that he was controlling. The tower controller said that, when flight 801 did not visually appear within 3 to 4 minutes after the airplane was cleared to land (about 0141:01), he commenced a communications search for the aircraft.[56] The controller attempted to contact flight 801 about 0145:13 and 0150:06. Between about 0150:00 and 0151:00, the tower controller queried the CERAP controller, the ramp controller, and an Andersen AFB controller about flight 801.

1.10.2 Instrument Landing System Ground-Based Equipment

FAA Form 6030-1, "Air Traffic Control Facility Maintenance Log," for July 7, 1997, showed that the Agana tower had been notified by an FAA maintenance technician that the glideslope portion of the ILS would be out of service starting that day for extensive reconstruction. The reconstruction work included the replacement of the glideslope's equipment shelter and all cabling and the upgrade of the power systems and grounding. A NOTAM issued by the FAA on July 7, 1997, indicated that the glideslope would remain out of service until September 12, 1997. The complete ILS system was flight checked, certified, and returned to service on August 31, 1997. The Safety Board's review of the facility maintenance log revealed no entries of pilot reports regarding the ILS or related navigation systems from July 7 to August 6, 1997.

The accident airplane's CVR recorded conversation among the flight crew regarding the operational status of the ILS glideslope as they approached the airport. For example, as previously stated in section 1.1, about 0139:55, the flight engineer asked, "is the glideslope working? glideslope? yeh?" About 0139:56, the captain answered, "yes, yes, it's working." About 0140:00, the first officer responded, "not useable." About 0141:46, the captain asked, "isn't glideslope working?"

In a postaccident interview, the captain of a Continental Air Micronesia 727-200 stated that, about 1530 on August 5, 1997, he was conducting an in-flight functional test of a newly installed global positioning system (GPS)[57] when the airplane's instrumentation showed an indication of the ILS glideslope,[58] even though the glideslope was out of service. Specifically, the captain stated that he was on approach to runway 6L at Guam International Airport and was centered on the localizer when he noticed that the glideslope was also centered and that no warning flags were associated with the ILS. In addition, the captain said that the glideslope always indicated "center" with no warnings even when the airplane was above the normal glidepath. The first officer confirmed the captain's observations. However, the flight crew did not indicate any anomalous glideslope indication to ATC personnel or submit any maintenance writeups containing such information.

The Continental Micronesia captain told Safety Board investigators that he originally assumed that the anomalous glideslope indication he experienced was caused by an airplane anomaly. The captain further stated that he thought the anomaly might have been a result of the GPS wiring installation. The captain did not report the glideslope anomaly to his chief pilot until 2 days after the Korean Air accident. The first officer stated that he and the captain "never thought twice" about the glideslope indications because they knew the glideslope was inoperative.

According to the maintenance records for the Continental Air Micronesia airplane, the first officer's ADI and HSI were removed and replaced on August 5, 1997, after the functional test flight. In addition, the records showed repeated squawks for the first officer's ADI and HSI between August 8 and 25, 1997.

1.10.3 Instrument Approach Procedures at Guam International Airport

Instrument approaches available for runway 6L at the time of the accident were the ILS (localizer only, glideslope out of service), the VOR/DME, and the VOR.

1.10.3.1 The Nonprecision Runway 6L Instrument Landing System Localizer-only (Glideslope Out) Procedure

The execution of the Guam ILS runway 6L localizer-only (glideslope out) approach requires the use of the NIMITZ VOR as a step-down fix[59] between the final approach fix (FAF) and the runway and DME to identify the step-down points.[60] The DME is not colocated or frequency paired with the localizer transmitter (which is physically located at the airport); rather, it is colocated and frequency paired with the NIMITZ VOR.

The nonprecision localizer-only approach requires the use of the localizer to obtain lateral guidance to the runway, the DME to identify the step-down points, and the VOR to identify the final step-down fix to the MDA. According to Jeppesen Sanderson's August 2, 1996, 11-1 ILS Runway 6L approach plate, the airplane should cross the FLAKE initial approach fix (IAF) — located at 7 DME from the VOR — at or above 2,600 feet msl. The nonprecision approach procedure prohibits descent below 2,000 feet msl (1,744 feet above airport elevation) before reaching the outer marker identified as GUQQY, which is the FAF and is located 1.6 DME from the VOR. Upon crossing the FAF, the procedure prohibits descent below 1,440 feet msl (1,184 feet above airport elevation) until passing the VOR. The procedure calls for a descent to 560 feet msl (the MDA, 304 feet above airport elevation), and the pilot is required to count up from less than 1 DME, as the airplane passes over the VOR, to 2.8 DME, the published missed approach point (MAP) and location of the middle marker. If a missed approach is not required, the airplane can continue its descent to the runway 6L threshold, located 3.3 DME from the VOR.

According to the FAA, the DME and localizer at Guam are now frequency paired and colocated. In addition, the August 27, 1999, Jeppesen instrument chart for the ILS runway 6L approach (which became effective on September 9, 1999) states "DME or RADAR required" and includes "ILS DME" in the frequency box.

1.10.3.2 Instrument Approach Charts for Guam International Airport

During postaccident examination of the cockpit area (which had separated from the main wreckage, as discussed in section 1.12), investigators found a clear plastic sleeve, measuring approximately 8 1/2 by 11 inches, that contained the following Jeppesen approach charts for Guam International Airport, all of which were dated January 19, 1996: 11-1, ILS Runway 6L; 13-1, VOR Runway 6L; 13-2, VOR DME Runway 6L; 16-1, NDB Runway 6L; and 16-2, NDB DME Runway 24R.[61]

Charts 11-1 and 13-2 were found side by side and were visible through one face of the plastic sleeve. Chart 16-1 and the blank side of an approach plate were visible through the opposite face of the plastic sleeve. Chart 11-1, which is shown in figure 7 [* page 27], had the following items highlighted with a green fluorescent tint: [62]

Plan view

ILS facilities box: 063° (inbound magnetic course), 110.3 (ILS frequency), IGUM (identifier), and FLAKE (IAF).

VOR facilities box: 115.3 (NIMITZ VOR frequency) and UNZ (identifier).

Profile view

2500' (msl altitude crossing FLAKE).

1900' (msl altitude crossing the outer marker).

256' (touchdown zone elevation — runway 6L).

The instrument approach charts for Guam International Airport in effect at the time of the accident were issued on August 2, 1996 (with an effective date of August 15, 1996). Changes incorporated in the August 2, 1996, 11-1, ILS runway 6L approach chart (shown in figure 1) included the location names, crossing altitudes, and the missed approach procedure. Table 2 [* page 28] details the specific differences between the January and August 1996 instrument approach charts.

1.11 Flight Recorders

1.11.1 Flight Data Recorder

The accident airplane was equipped with a Sundstrand Data Corporation model 573A FDR, serial number 2663, which was configured to record 51 parameters. The FDR recorded

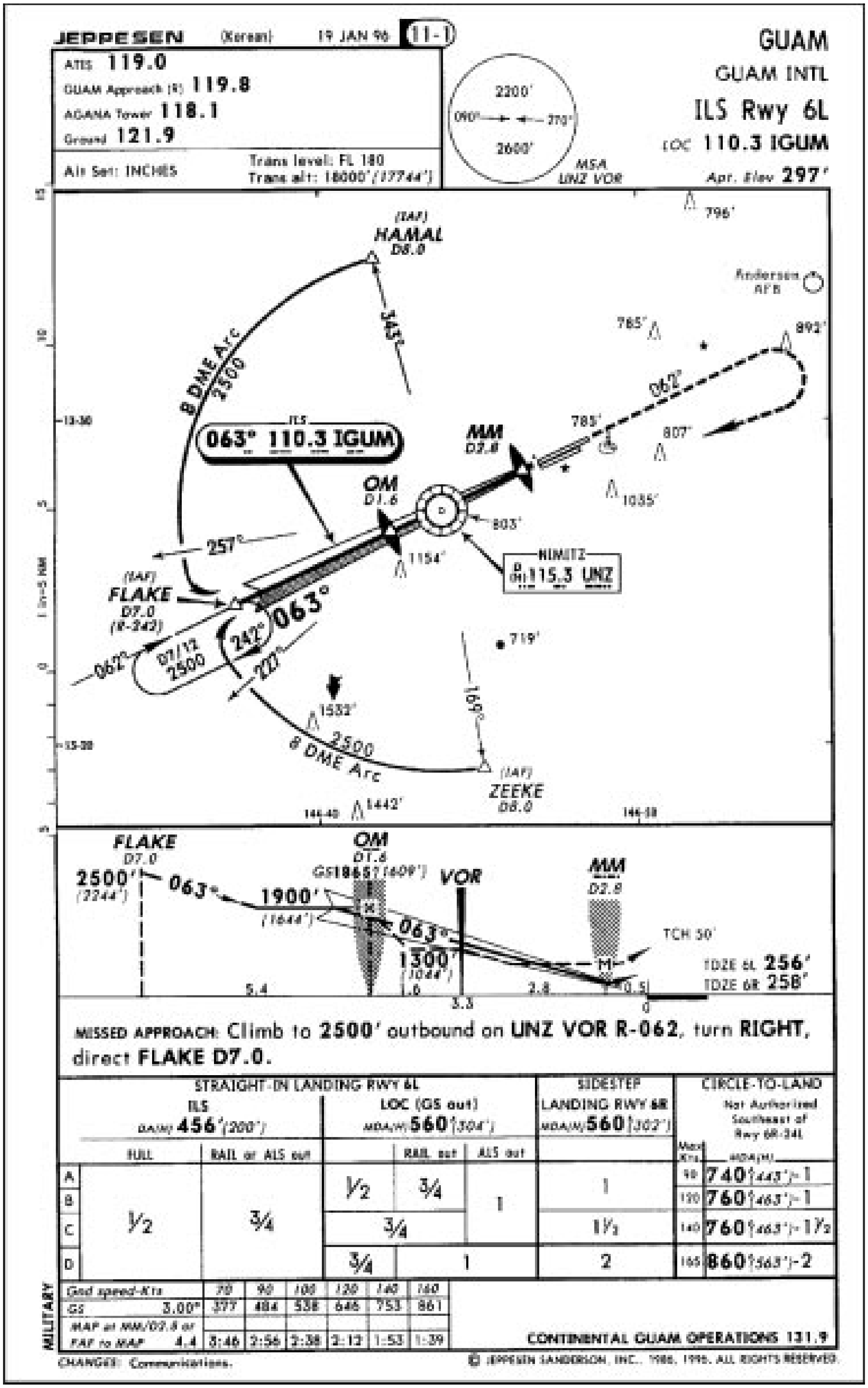


Figure 7. The January 19, 1996, 11-1 ILS runway 6L instrument approach chart.

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Table 2. Information differences between the January 19 and August 2, 1996, Guam ILS runway 6L approach charts.

Chart dated January 19, 1996	Chart dated August 2, 1996
No note regarding DME requirement.	Note on chart stating DME REQUIRED. DME from UNZ VOR.
MILITARY (in amendment block).	AMEND 0 (in amendment block).
HAMAL (IAF) is 8 DME on R-343.	HAMAL (IAF) is 7 DME on R-343.
ZEEKE (IAF) defined as 7 DME on R-169.	ZEEKE defined as 7 DME on R-169.
FLAKE (IAF) defined as 7 DME on R-242.	IAF is defined as 7 DME from UNZ on the localizer.
FLAKE (IAF) crossing altitude is 2,500 feet.	7 DME fix (IAF) on the localizer; crossing altitude is 2,600 feet.
Outer marker fix designated OM.	Outer marker fix designated GUQQY.
Outer marker crossing altitude is 1,900 feet.	GUQQY crossing altitude is 2,000 feet.
VOR crossing altitude is 1,300 feet.	VOR crossing altitude is 1,440 feet.
Missed approach point designated 2.8 DME at the middle marker.	Missed approach point depicted in large, bold font: **D2.8 UNZ VOR, M**M
Touchdown zone elevation for runway 6L.	Touchdown zone elevation for both runways 6R and 6L.
Sidestep minimums included.	Sidestep minimums deleted.
Missed approach procedure: Climb to **2500'** outbound on **UNZ VOR R-062**, turn **RIGHT** direct **FLAKE D7.0**.	Missed approach procedure: Climb to **2600**, then turn **RIGHT** via **UNZ VOR R-242** to **FLAKE D7.0 UNZ VOR** and hold **SOUTHWEST, RIGHT** turn, **062**° inbound.
Holding pattern at FLAKE depicted.	No holding pattern at the IAF or FLAKE depicted.
No obstruction symbol depicted at the VOR. 7	24-foot obstruction symbol depicted at the VOR.
803-foot elevation shown for UNZ VOR.	No elevation shown for UNZ VOR.
1,154-foot elevation at outer marker.	1,190-foot obstruction shown at GUQQY.
1.6 DME at outer marker depicted on plan view.	1.6 DME UNZ VOR at GUQQY depicted on plan view.
No note for FLAKE.	Note added: (FLAKE) for missed approach only.

information digitally on four tracks using 1/4-inch-wide magnetic tape that had a recording duration of 25 hours before the oldest data were overwritten. Even though the FDR case was damaged by impact forces, data could be retrieved and analyzed. Examination of the data indicated that the FDR had operated normally, except for a loss of synchronization about 3 seconds before the transition to 25-hour-old data. About 3 hours 48 minutes of data were transcribed for the entire accident flight (takeoff to impact).

After an initial readout of the FDR, Korean Air provided the Safety Board with documentation that indicated that 11 additional sensors had been retrofitted after the airline took delivery of the airplane. These retrofitted sensors — exhaust gas temperature and oil quantities for the airplane's four engines, static air pressure, and the left No. 4 and right No. 12 spoiler positions — were not reflected in the FDR documentation provided by the manufacturer or the airline at the time of the initial FDR readout. Documentation for the additional sensors provided by Korean Air did not include the equations necessary to convert the recorded information into engineering units.[63] The Safety Board applied equations used in previous readouts of FDRs from similar 747s, but the validity of the conversion equations could not be verified.

1.11.2 Cockpit Voice Recorder

The accident airplane was equipped with Fairchild model A-100A CVR, serial number 61216. The CVR case revealed no evidence of structural damage, and the interior of the recorder and the tape showed no evidence of interior heat or impact damage. The recording consisted of four channels of "good quality" audio information,[64] which included the captain, first officer, and flight engineer microphones; audio panels; and the cockpit area microphone. The fourth channel also recorded the interphone and the public address system.

The audio portion began about 0111:42 and continued uninterrupted until 0142:32.53. The recording ended shortly after the airplane crashed and the power to the CVR was lost. The CVR group, consisting of representatives from the parties to the investigation and the KCAB, collectively transcribed the 31-minute 1-second tape in its entirety. A bilingual (English and Korean) transcript was produced of the entire recording (see appendix B).

1.12 Wreckage and Impact Information

1.12.1 General Wreckage Description

Examination of the ground scars and the debris pattern revealed that the accident airplane impacted high terrain with the left outboard engine, main landing gear, and left wing at an elevation of about 660 feet msl and on a magnetic heading of approximately 063°.

The Safety Board performed a complete survey of the accident site and airplane structure. The main wreckage site area was in a gully covered with dense vegetation, located approximately 2,000 feet southwest of the NIMITZ VOR. The wreckage distribution area was about 2,100 feet long and 400 feet wide and included airplane debris, tree strikes, and ground impact marks. All major structural components of the airplane and control surfaces that were not consumed by the postimpact fire were identified along the wreckage path. The terrain along the wreckage path was hilly and ranged from about 673 feet msl at the first tree strikes to about 582 feet msl at the main wreckage area.

The initial point of impact was evidenced by several cut treetops that extended along the wreckage path. Several ground impact marks, consistent with the main landing gear, were found in the vicinity of the broken oil pipeline, located about 400 feet from the point of initial impact. A ground scar, about 89 feet long, 6 feet wide, and 2 feet deep, was found about 415 feet from the point of initial impact, and several pieces of the No. 1 engine cowl were found embedded in this area, along with parts of the left wing leading and trailing edge flap structure.

Numerous parts of the left main landing gear, including two wheels and tires, were found embedded in a small berm about 1,430 feet from the initial impact point. Most of the fuselage structure was located in the main wreckage area and was found separated into five major sections: the empennage, the aft fuselage, the center fuselage, the forward fuselage, and the cockpit.

Figures 8a and 8b [* page 30] are photographs of the wreckage from Korean Air flight 801. Figure 8a shows the airplane

Figure 8a. Wreckage from Korean Air flight 801 in relation to Guam International Airport runway 6L (upper middle), the NIMITZ VOR (upper right) and Apra Harbor (upper left).

Figure 8b. Closer view of the wreckage from Korean Air flight 801 and the NIMITZ VOR.

wreckage in relation to runway 6L, the NIMITZ VOR, and Apra Harbor.[65] Figure 8b provides a closer view of the wreckage and the VOR.

1.12.2 Fuselage and Empennage

The cockpit section was located down an embankment beyond the large portion of the forward fuselage. The airplane's VHF [very high frequency] navigational radio control panels were recovered from the wreckage. To determine which radio frequencies were selected on both the captain's and the first officer's control panels in the cockpit, an examination was conducted on October 2, 1997, under the Safety Board's supervision, at Pacific Aero Tech, an FAA-approved repair station for the control panel, in Kent, Washington. The captain's frequency selector was found tuned to 110.30 megahertz (MHz), which was the Guam localizer frequency. The captain's control panel had been damaged by impact forces, and the frequency depicted was locked into a position that could not be changed by turning the frequency selector knob. The first officer's control panel selector knob could be easily rotated, and the frequency selector was found tuned to 116.60 MHz, which did not correspond to any voice or navigation frequencies at Guam.

The cockpit section was found separated about station[66] 400. Most of the aft nose wheel well structure (nose gear attachment point) was relatively intact with the trunnion support fittings, drag brace fittings, and transverse beam still attached. Examination of the nose landing gear and the wing- and body-mounted landing gear revealed that they were in the extended position at the time of impact. This section of fuselage structure revealed no evidence of fire damage.

The forward fuselage section approximately from stations 400 to 1120 was located on the upslope of a hill beyond the center fuselage section. The fuselage structure was split above the main deck floor on the right side, and most of the internal structure (frames, stringers, and fractured floor beams) remained attached. The structure exhibited extensive fire damage, including burn-through of the crown area (upper forward fuselage), sidewalls, and floor.

Examination of doors 1L, 1R, 2L, and 2R could not be performed in detail because the airframe structure around these doors was heavily burned, and only portions of the doors were located in the main wreckage site. The door identified as 3L was found closed and locked. Door 3R was found separated from the fuselage, with more than one-half of the door frame area missing because of fuselage separation in this area. According to Korean Air records, the 3L and 3R doors were deactivated before the company took delivery of the airplane. The doors identified as 4L and 4R were found detached from their respective mounted positions, and approximately one-third of the 4R door frame was missing. Door 5L was found closed and locked. Door 5R was found in the open position; however, the door handle was not in the full open position. The upper deck doors were not located; these doors were mounted in an area of the fuselage that sustained extensive fire damage.

The center portion of the fuselage structure, extending from stations 1120 (left side) to 1240 (right ride) and aft to station 1780, was found attached across the crown area and to the right wing by the landing gear beam. The landing gear beam at station 1350 was attached to the fuselage section. The entire center section was found rotated about 180° to the debris path, with the forward end of the section facing the aft body and empennage. The interior was extensively damaged by fire throughout the section. The exterior fuselage skin bore fire damage primarily adjacent to the break, and the right-side fuselage skin was heavily burned between doors 3R and 4R.

The exterior fuselage surface was lightly sooted on the left side of the center section, and the exterior of the right side bore evidence of light soot and areas of fire damage around the periphery of door 5R. The interior was damaged by fire from the main deck floor level to the belly; however, the upper portions of the internal structure were not burned significantly. The aft pressure bulkhead was intact, with the lower portion deformed. The bulkhead was not damaged by fire.

The empennage was found separated from the aft fuselage in an upright position. The empennage had sustained impact damage and some light fire damage. The left- and right-side horizontal stabilizers, their respective elevators, and the vertical fin (with the rudder attached) remained attached in their respective mounted positions.

1.12.3 Wings

The left and right wings were located on the left side of the airplane in the main wreckage area. The right wing remained attached to the fuselage center section, and the left wing was located under the fuselage and right wing.

The outboard section of the left wing was located approximately parallel to and under the right wing section. This portion of the left wing structure was approximately 80 percent intact and had sustained extensive postimpact fire damage to the upper skin and midspar (between wing stations 470 and 1200), including the midspar web and chord structure. The corresponding lower skin and stringers also exhibited considerable fire damage. Exposure to the postimpact fire resulted in various degrees of damage to the remaining wing structure, including the leading edge and trailing edge flap structure. The outboard wing tip, which comprised 10 composite aluminum and fiberglass structures, was found separated from the wing box at the surge tank end rib at wing station 1548 and was not damaged by fire.

Most of the right wing inboard and outboard trailing edge flaps and support structure were found intact and attached to the wing box, except for approximately 6 feet of the inboard fore, mid, and aft flap structure of the inboard-most section of the flap. This section had separated and was found in the debris path in the vicinity of the initial impact point. Examination of the ball screw indicated the flap extension was approximately 25°.

All of the leading edge variable camber flap and inboard Krueger flap structure was destroyed by impact forces and the postcrash fire. The trailing edge flaps and control surfaces were found relatively intact with some localized fire damage, except for the inboard flap system, No. 4 flap track, and No. 6 spoiler, which separated from the wing box during initial impact.

The No. 1 through No. 5 flight spoilers were found in place in a neutral position at the in-spar box structure. The spoilers exhibited extensive fire damage. The No. 6 ground spoiler had separated from the wing and could not be located among the wreckage. Examination of the spoiler support beam revealed evidence consistent with overload from impact forces.

The full combination of outboard flap and support structure on the left wing was found in place on the wing box with a detent extension indicative of approximately 25°. All of the inboard flap and most of the support structure had separated from the wing box and was found along the wreckage path, with numerous parts in the area of the initial impact point.

1.12.4 Engines

All four of the engines were found separated from their respective mounted positions on the airplane. The No. 1 engine was located about 970 feet from the initial impact point and about 1,300 feet from the main wreckage site. The other three engines were all located within the main wreckage site.

All of the engines sustained damage to the fan blades, with the tips and leading edges bent opposite to the direction of rotation. Further, vegetation and dirt had been ingested into the fans and low-pressure compressors of each of the engines. Examination of the rotating parts within each engine revealed evidence of rotational smearing, rubbing, and blade fractures that were consistent with the engines producing power at the time of impact. Further, none of the four engines exhibited any evidence of uncontained failures, case ruptures, or in-flight fires. All of the thrust reverser actuators that were found indicated that the thrust reversers on each of the engines were in the stowed position.

1.13 Medical and Pathological Information

Tissue and fluid samples from both pilots and the flight engineer were transported to the FAA's Civil Aeromedical

Institute (CAMI) for toxicology analysis. The CAMI laboratory performed its routine analysis for major drugs of abuse and prescription and over-the-counter medications, and the results were negative. The analysis detected ethanol in the blood and tissue samples of both pilots and the flight engineer, but no ethanol was detected in the vitreous (eyeball) fluid sample taken from the captain. All specimens were noted in the laboratory report to have been received by CAMI in a "putrefied" condition.

According to the captain's medical records, he consulted a personal physician on July 27, 1997, and was diagnosed with bronchitis. The physician prescribed three medications: Copan (clenbuterol), a medication to open the upper airways; Vibramycin (doxycycline), an antibiotic; and Sentil (clobazam), a medication in the benzodiazepine class of drugs that is frequently used as a sedative.[67] The postmortem tests conducted by CAMI on the captain's blood specimen were negative for benzodiazepines, and no CAMI testing was available for the detection of Copan or Vibramycin.

The remains of deceased airplane occupants were examined by the Disaster Mortuary of Guam to determine the cause of death. Because many of the remains were fragmentary, the total number of remains sets (300) exceeded the number of accident fatalities. Autopsy examinations and toxicological analysis determined that the airplane occupants died of blunt force trauma, thermal injuries, and carbon monoxide inhalation. Complete autopsies and toxicological evaluations were performed on the remains of the three flight crewmembers (as discussed previously.) Of the 297 non-flight crewmember sets of remains, about 145 sets could not be evaluated for soot in the airway because the condition of the remains precluded an evaluation. Of the 137 remains sets that could be evaluated, soot was found in the airway of 20 sets, no evidence of soot was found in 41 sets, and no definitive observations could be made regarding soot in the airway for 76 sets (in many of these 76 cases, however, the traumatic injuries described would have precluded survival after the impact sequence). Information was not available for the final 15 sets of remains.

1.14 Fire

A fire erupted during the impact sequence and was sustained by the fuel on board the airplane; the last report of small remaining fires was about 0800. The Safety Board's investigation revealed no evidence of an in-flight fire.

1.15 Survival Aspects

1.15.1 General

The 747-300 cabin contained a total of 385 passenger seats and was divided into three sections: first class, prestige (business) class, and economy class. The airplane was configured with four rear-facing, double-occupancy flight attendant jumpseats and six rear-facing, single-occupancy flight attendant jumpseats, all of which were equipped with a four-point restraint system. The flight attendant seats were located at each of the four emergency exit doors located on the left and right side of the cabin.

Of the 237 passengers aboard flight 801, 3 were children between 2 and 12 years old, and 3 were children 24 months or younger. Thirty-one airplane occupants were found alive by rescue workers Two passengers died en route to area hospitals. The autopsy report for one of these two passengers did not identify a single cause of death (her remains showed evidence of multiple internal injuries but no burns or soot in her airway). The autopsy report, however, identified that she was alive when medical personnel arrived at the accident scene and that she was treated aggressively as a result of serious injuries. In addition, 3 passengers died of their injuries within 30 days after the accident, bringing the official total number of accident survivors to 26.

Of the 26 survivors of the accident, 7 passengers and 1 flight attendant were seated in the first class section, 1 flight attendant was seated in the prestige class section, 7 passengers were seated in the forward economy class section, and 9 passengers and 1 flight attendant were seated in the aft economy class section. Two of the surviving flight attendants and 13 of the surviving passengers were seated on the right side of the airplane; 6 of these 13 passengers were seated over the right wing. Figure 9 [* page 33] shows the 747-300 cabin configuration and the survivor seat locations.

1.15.2 Survivor Statements

Safety Board investigators and MOCT officials interviewed a surviving flight attendant and several passengers in a Guam hospital on August 9, 1997. In addition, 11 passengers responded to a Safety Board "Survivor Questionnaire" after returning to Korea. Information obtained from the interviews and questionnaire responses indicated that these survivors either had been ejected from the airplane during the impact sequence or had extricated themselves from the wreckage. Most of these survivors indicated that they were injured as a result of the impact; however, two survivors stated that they were injured by fire. Further, the survivors stated that, during their egress from the airplane, they encountered damaged seats, overhead that had fallen, and other unidentified obstacles.

A flight attendant who was seated in the R1 jumpseat (in the first class section) stated that she heard a loud "boom" before the airplane began shaking violently and breaking up. The flight attendant said that she was thrown from the airplane in her jumpseat during the impact. She then unfastened her restraint system, walked about 30 feet beyond the right side of the airplane, and assisted a female passenger.

Several surviving passengers stated that, after the impact, baggage from the overhead bins fell to the floor and that

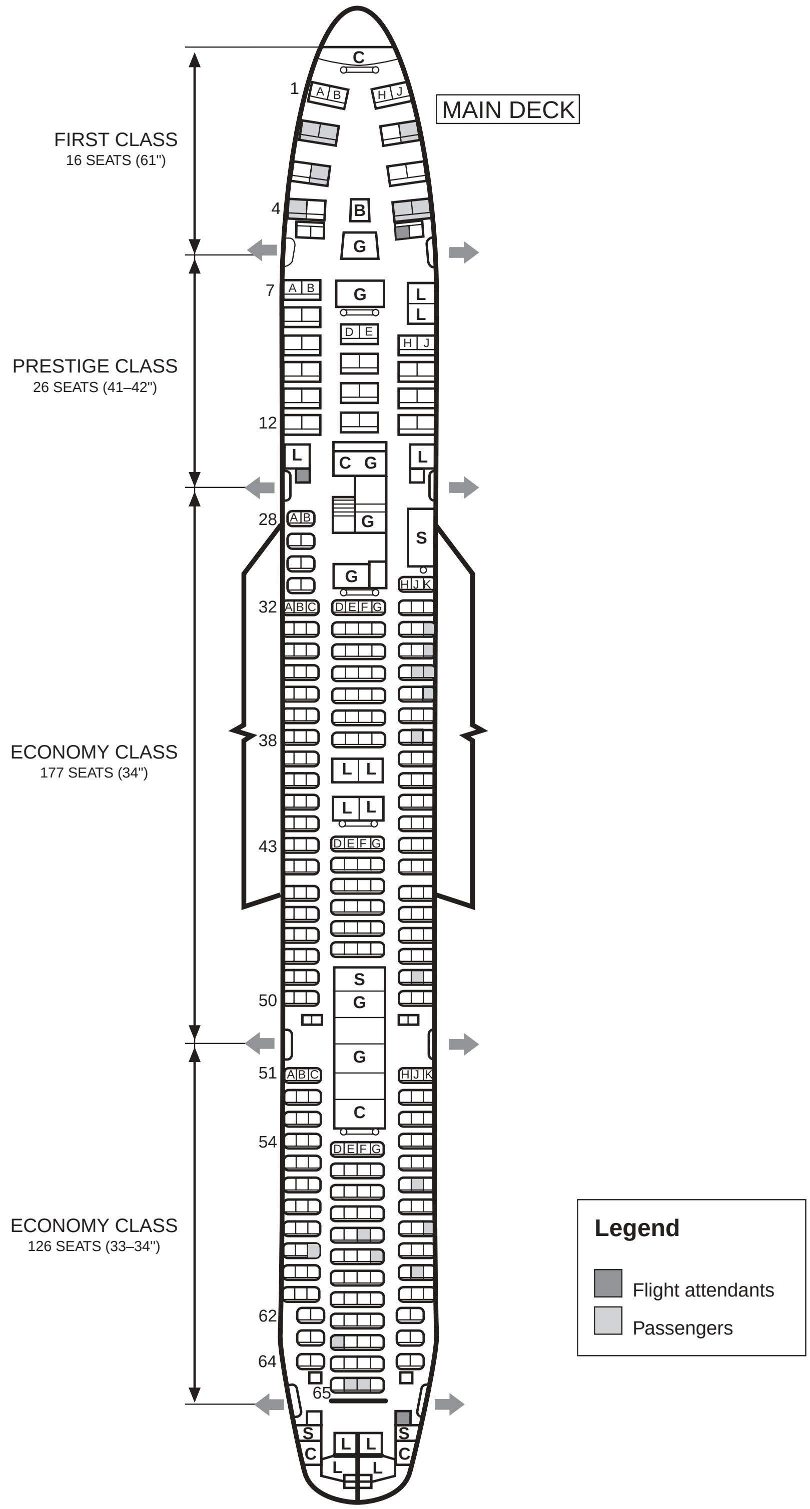

Figure 9. Korean Air flight 801 cabin configuration and survivor seat locations.

"intense flames and heat swept through the cabin." One survivor, who was seated in the aft economy class section (row 34), stated that her husband was engulfed by fire in the seat next to hers. Another passenger, a professional helicopter pilot, stated he felt what he thought was a "hard landing" but that the airplane then rolled and began to disintegrate. The passenger stated that he exited the burning cabin by walking through a large hole in the fuselage. He also said that a "ball of flame was going down the center of the airplane" and that passengers were screaming and calling for help.

1.15.3 Emergency Response

About 0150, the Guam Fire Department (GFD) communications center received an emergency call from a local resident, who reported seeing a fire in the hills near the airport. About 0158, after receiving notification of the accident from the CERAP controller (based on the Ryan International flight crew's observation of a "big fireball on the hillside"), the Agana tower controller alerted ramp control about the crash of Korean Air flight 801.[68] According to airport ramp control logs, ramp control initiated the required emergency notifications at 0202, including a call at 0208 to the Naval Regional Medical Center to place its personnel on standby. According to GFD communications center logs, notification of a downed aircraft was received from the Guam ramp control at 0207. Immediately afterward, the GFD communications center dispatched Engine Company No. 7, which was located about 3 1/2 miles from the accident site. According to the GFD chief, the departure of Engine No. 7 was delayed because its brakes had been drained to prevent an overnight buildup of condensation in the brake lines.[69] Thus, the brake lines had to be first recharged with air. Engine No. 7 departed the station at 0219 (12 minutes after being notified) and arrived 15 minutes later (at 0234) at the gate to the pipeline/VOR access road (which was the only vehicle ground access to the accident site).

The Federal Fire Department's Station No. 5, located on Nimitz Hill 1 mile away from the accident site, was the nearest fire station.[70] GFD communications center logs indicated that the federal dispatch facility was notified of the accident at 0207, but the federal dispatch facility records indicated that notification was received at 0234 and that Engine No. 5 arrived at the scene at 0239.

The Chief of Staff, Commander, U.S. Naval Forces, Marianas, who was also the wife of the airport director, testified during the public hearing that she first became aware of the crash after an airport official called her husband at 0216 to report that a Korean Air 747 was missing over the Nimitz Hill area. The Chief of Staff went outside and observed a "bright orange glow" in the sky. She then notified the Navy Security Office and Command Duty Officer to activate the Navy's "first responders," search and rescue assets, and hospital mass casualty units.

The GFD incident on-scene commander (OSC) told investigators that he arrived at the accident site about 0234 and proceeded down the access road toward the wreckage. The access road to the site — a narrow (one-lane) dirt and stone road with a drainage ditch on both sides — had been blocked by a section of damaged oil pipe. The pipe, which was located next to the road and elevated about 3 feet, was removed 1 hour later by a truck-mounted winch after efforts to remove it by hand were unsuccessful. According to GFD documents, Engine No. 7 became stuck in mud when the driver tried to maneuver around the oil pipe obstruction. The GFD chief stated that, once the broken pipeline had been removed and the fire truck had been towed out of the mud (about 0345), no further blockages of the access road were reported.

In a postaccident interview and at the Safety Board's public hearing, the OSC testified that he and other rescue personnel abandoned their vehicles and approached the accident site on foot. The OSC indicated that he and the rescue personnel carried flashlights, rope, and a trauma kit. The OSC stated that he heard people screaming and could see small areas of fire. The OSC said that the darkness and terrain made access to the accident site difficult.

The OSC stated, "we had to go across all types of vegetation, sword grass, all types of trees … it was very rough getting down to the crash site, especially with no light whatsoever but flashlight alone … we had to deal with all kinds of bugs down there, snakes … we tried to pull out the survivors the best way we could and from what we received in fire-fighting training." The OSC also stated that

> the airplane [had been] totally engulfed [in fire] when we got there … already to the point where the fires weren't really bothering the rescuers. The rescue personnel were actually going into the plane checking passengers … who was still alive and who was not … . We had to go back up on those slippery hills without any rappelling gear whatsoever … . We were holding the victims in one arm and holding the tools in the other so we just could make it to the top … . We did this until we could clear a landing site for the choppers … .

The OSC stated that a command post was established to the east (on higher terrain) of the main wreckage site, where requests for resources and personnel were relayed by radio to the GFD dispatcher. The dispatcher then relayed the information to the response activity coordination team located at Guam Civil Defense (GCD) headquarters.

The GCD director told Safety Board investigators that he arrived at the access road gate about 0235. The director stated that the GCD owned a command post vehicle but that he did not use the vehicle because it was outdated and had been out of service for several years. He stated that funds were not available to repair and equip the vehicle.[71]

A U.S. Navy emergency medical technician (EMT) assigned to the Naval Regional Medical Center told Safety Board investigators that he received verbal notification of the accident between 0200 and 0230 from personnel at the Guam Naval Activities Station, which is located about 8 miles southwest of Nimitz Hill. The EMT reported that he arrived at the accident site on foot between 0245 and 0300. Upon arrival, the EMT observed the fuselage and interior engulfed in "bright blue flames." The EMT stated that he approached the burning wreckage to within about 150 feet and saw about 14 survivors outside the airplane with various injuries, most of which were burn related. The EMT said that many of these survivors were clustered together and that they appeared to have extricated themselves from the wreckage.

The EMT told investigators that it was difficult to maneuver around the wreckage because of darkness, intermittent rain, soft ground, tall grass, and rugged terrain. Further, the EMT stated that two triage areas had been set up: one near the front of the airplane (near the nose section), and the other between the fuselage wreckage and the access road.

A Guam Department of Public Health physician told Safety Board investigators that she was notified of the accident by GCD about 0245 and arrived at the accident site about 0315. Upon arrival, she noted that the triage and transportation activities were "functioning well" but that medical and evacuation efforts lacked coordination. Additionally, she said that, after assessing the situation, she established another triage area near the VOR, where the terrain was level.

Some of the survivors that had been treated at the triage area near the airplane were evacuated by military helicopters, whereas others had been carried to the triage area near the VOR to be treated and then transported by ambulance via the access road. The OSC stated that the first survivors were transported to hospitals between about 0300 and 0330. The EMT stated that the last survivor was found about 0430. According to hospital records, the first survivor transported by helicopter to the U.S. Naval Hospital arrived about 0334, and the last survivor arrived by helicopter about 0710. Also, hospital records indicated that the first survivor transported to Guam Memorial Hospital arrived by ambulance about 0420 and that 16 other survivors were transported by ambulance to Guam Memorial, the last of which was admitted about 0709.[72]

1.15.3.1 Emergency Response Planning and Exercises

At the Safety Board's public hearing, the GCD director testified that, in April 1997, a joint full-scale disaster drill had been conducted on the airport with Guam airport authorities.[73] The GCD director stated that no off-airport drills had been conducted before the accident but that an off-airport aircraft accident drill had been scheduled for September 1998. The GCD director added that, after the accident, new radios had been purchased to allow interagency communication and coordination during emergencies.

The GCD director also testified that, before the accident, GCD authorities had a memorandum of understanding (MOU) with the U.S. Air Force for emergency response but had not established an MOU with the U.S. Navy or U.S. Coast Guard. The GCD director stated that, after the accident, Guam authorities formed an emergency response committee, which included the Navy, the Coast Guard, and the Air Force, and that an MOU involving all emergency response agencies on the island had been drafted. The director stated that the MOU called for emergency response drills involving all of the agencies.

In June 1999, the GCD acting administrator stated that, instead of the MOU, a final draft of "Joint Standard Operating Procedures for Mutual Civil Emergency Support for Emergencies or Disasters Without Presidential Declaration" was circulated to the GCD office; Commander, Naval Forces Marianas; U.S. Coast Guard Marianas Section; and the U.S. Air Force 43rd Air Base Wing. The acting administrator indicated that the procedures could be implemented by the end of June 1999. The Safety Board's latest information from the GCD office (August 1999) indicated that the procedures had not been implemented.

Officials from the GCD office stated that the planned September 1998 off-airport exercise did not take place. In June 1999, the GCD acting administrator stated that planning for a major off-site exercise had started.

1.15.4 Guam Governor's Accident Response Review

The Guam government conducted a review of its response to the accident and issued a report, titled *Korean Air 801 Incident Report*. According to the report, the "focus of the investigation was to identify an accurate timeline of emergency response during the first hours of the incident, and to address issues/questions raised concerning the rescue efforts. Those issues/questions concerned fire suppression, command structure and activity of key members of the rescue team."

Problems discussed in the report included the lack of radio communications between key personnel, which complicated the command situation. The report stated, " … the civilian and military components were on different and incompatible radio systems … radios had to be shared in the command post so that the various agencies could communicate."

Additionally, the report cited the remoteness of the accident site and the difficulty in bringing fire trucks close enough to the site to be effective. However, the report stated that "no fire suppression was used" because it would have "interfered with rescue operations."[74] The report also cited accounts from rescuers that indicated, " … most of the survivors were initially located away from the flames of the aircraft … . It is noted that the first rescuers arrived approximately 55 minutes after the plane had crashed … . If the fire was as intense as originally reported [immediately after impact], fatalities caused by fire and smoke inhalation would have occurred before the rescuers arrived."

1.16 Tests and Research

1.16.1 Enhanced Ground Proximity Warning System Simulation

Because of advances in computer technology and terrain mapping capabilities, GPWS manufacturers have developed improved terrain avoidance systems. In 1997, the FAA certified a new terrain awareness and warning system (TAWS), also known as enhanced GPWS. (See section 1.18.2.2 for general information about enhanced GPWS.) This system was not installed or required on the accident airplane.[75]

An enhanced GPWS simulation was conducted after the accident to determine the additional forewarning that the flight crew of Korean Air flight 801 would have received if such a system had been installed on the airplane. The simulation revealed that the flight crew would have received an aural "CAUTION TERRAIN" warning and a yellow visual terrain depiction on the weather radar about 60 seconds before impact. In addition, enhanced GPWS would have provided the aural annunciations "TERRAIN, TERRAIN" and "PULL UP" and a red visual terrain indication on the weather radar display about 45 seconds before impact; the annunciations would have sounded continuously until completion of a successful escape or impact with terrain.

In July 1999, Korean Air announced that it would equip all of its aircraft with enhanced GPWS by the end of 2003. The KCAB subsequently confirmed Korean Air's announcement.

1.16.2 Minimum Safe Altitude Warning System Simulation

An ARTS IIA MSAW simulation was conducted after the accident at the FAA Technical Center in Atlantic City, New Jersey. The simulation indicated that, without the 54-nm-inhibited ring, a visual and aural low-altitude alert would have been generated for flight 801 on the terminal ARTS IIA display at the CERAP facility. Further, the simulation indicated that the visual and aural approach path alert would have been generated at 0141:22, as the airplane was descending through 1,700 feet msl, or about 64 seconds before the airplane crashed.

1.16.3 Korean Air Spurious Radio Signal Tests

After the accident, the KCAB and Korean Air conducted a series of independent tests on a Boeing 747 on the ground to determine if spurious radio-frequency energy could induce an abnormal ("false") glideslope indication. These tests were not intended to represent conditions at the time of the accident; rather, the tests were designed to explore ILS system sensitivity to spurious signals. According to Korean Air engineers, the tests revealed that the glideslope deviation needle could be positioned near the middle of the glideslope reference scale, and the warning flag could be retracted by introducing a "335 MHz signal (120 Hz signal modulated at 100 percent)" near the ILS receiver antenna.[76]

The KCAB and Korean Air technical staff demonstrated their test results to the Safety Board and parties to the investigation at a January 1998 meeting. The demonstration, which was conducted using a portable 51-RV5(B) receiver and a signal generator, indicated that a single 120-Hz signal with 100-percent modulation at the Guam ILS frequency resulted in an out-of-view glideslope flag and glideslope indicator movement.

If a glideslope signal is not being generated by the transmitter (resulting in an open frequency channel/band), the airborne glideslope receiver will continue to hunt for a glideslope signal. Although the radio-frequency filters built into the receivers are designed to bias out the majority of spurious radio signals, the postaccident testing by the KCAB and Korean Air revealed that, in the absence of a valid glideslope signal, it is possible for an airborne glideslope receiver to momentarily receive a spurious signal in the frequency band of the glideslope signal. The reception of such a signal could result in the movement of the glideslope receiver needle and present a false indication to the pilot.

1.16.3.1 Guam Instrument Landing System and Potential Interference From Spurious Radio Signals

An FAA National Resource Engineer for Navigation testified at the Safety Board's public hearing about the Guam ILS system and the potential for interference from spurious radio signals. The engineer stated that "the pilot would normally be warned that a signal is not present by the presence of a flag, a warning flag, that indicates that something about the receiver system or something about the ground system is abnormal … ." The engineer testified that he assumed that the accident flight crew's remarks regarding the glideslope (as recorded on the CVR) had to do with the presence or absence of flags. He concluded that " … there must have been some sort of flag activity coming into view, disappearing from view, some time during the approach" and that the comments, although they did not convey information about the duration of any flag activity, indicated that " … there must have been enough absence of the flag for the crew to occasionally decide that the system was on the air when in fact it wasn't … ."

The FAA engineer also testified that, although the glideslope at Guam International Airport had been removed from its shelter, radio signals generated by some other source could have provided an intermittent signal to the glideslope receiver, which might have prevented the instrument warning flag from remaining in view. The engineer explained that potential external sources of noise and unintended signals, which are normally too weak to be heard, can be heard on an empty channel and that, during airborne flight tests of ILSs in which the localizer or the glideslope is turned off, it has been fairly common for the cockpit instrumentation to record intermittent indications of flag and needle activity. However, he expressed that this sort of activity on the instrumentation (referred to by pilots as "flag pops") is typically intermittent and of very short duration.

The engineer testified about the types of radio signals that could potentially cause a movement of the flag. He stated that the

ILS transmits two tones and that the difference in the signal strength of the tones deflects the glideslope fly-up and fly-down needle. The engineer indicated that the receiver has some circuits that look for these two tones and that the fly-up/fly-down needle indicates the difference in strength of those two tones. He added that " … the difference will be zero, and the needle will be centered when the two tones are equal … ."

Further, the FAA engineer stated that the flag circuit, the other indication that a pilot sees, is driven by a signal that is the sum of the two circuits or the two signals. He indicated that "as long as the 90 and 150 [Hz] signals are both present at sufficient strength, the flag will remain out of view." The engineer also stated that, if there is no ground station transmitting and no intended ground station but some other signal, then those portions of the signal that contain 90- and 150-Hz tones[77] would still get through those filters and could cause the needles to deflect. The engineer added that, depending on the shape of the filters' response (which varies according to receiver model and manufacturer), the circuits would experience varying amounts of intermittent deflections.

1.17 Organizational and Management Information

Korean Air evolved from Korean National Airlines, a government-owned carrier established in 1948 to provide domestic air service from Seoul to Pusan. The airline was privatized in 1969 and renamed Korean Airlines. The name was again changed to Korean Air Company, Ltd., d.b.a. Korean Air, in the 1980s.

Korean Air, based at Seoul's Kimpo International Airport, operates domestic routes to 16 airports and international routes to 54 airports, including those in North America, Europe, the Middle East, Southeast Asia, China, Australia, and Japan. At the time of the flight 801 accident, Korean Air had a fleet of 116 airplanes: 2 Boeing 747-SPs, 15 Boeing 747-200s, 3 Boeing 747-300s, 26 Boeing 747-400s, 2 Boeing 777s, 5 McDonnell Douglas MD-11s, 14 McDonnell Douglas MD-82s, 10 Airbus A-300s, 2 Airbus A-330s, 25 Airbus A-00-600s, and 12 Fokker F.100s. Korean Air stated that its fleet was expected to grow to approximately 175 aircraft by 2005.

Korean Air employed approximately 1,600 flight crewmembers at the time of the flight 801 accident. In an interview with Safety Board investigators, Korean Air management personnel stated that pilot recruitment at the company had historically been from the Korean military. However, as the airline grew, the supply of available Korean military pilots could not keep pace with the rapidly increasing demand for pilots at the company. Because of this shortage, Korean Air recruited foreign nationals to supplement its pilot force. At the time of the accident, 167 foreign national pilots were employed by Korean Air. (Most of these foreign pilots were from the United States and Canada and were hired through several crew leasing companies; the pilots' employment was subject to the terms of a renewable contract.) Of the 128 captains assigned to 747-200, -300, and -SP airplanes at the time of the accident, 69 were foreign national pilots.

Also, partly as a result of the pilot shortage, Korean Air began what it referred to as an "ab-initio" (that is, from the beginning) program in 1989 that was designed to select and train candidates from zero flight time. According to a Korean Air representative, ab-initio-trained pilots were initially assigned to the smaller airplanes used to fly domestic routes. As the pilots gained experience, they were upgraded to the larger airplanes used primarily to fly international routes. At the time of the accident, 389 pilots had been trained under the ab-initio program, and Korean Air estimated that the first group of ab-initio pilots would be evaluated for possible upgrade to captain during 1998. In September 1999, a KCAB official stated that the first ab-initio-trained pilots were being upgraded to captain.

The Korean Air Deputy Director of Flight Operations testified at the Safety Board's public hearing that the Korean economy had been in a recession and that, although 1995 was "a good year," 1996 and 1997 were "in the red." This official also testified that, despite economic pressures, additional funding had been allocated by the company for safety programs. The Deputy Director of Flight Operations, in his closing remarks at the public hearing, stated:

> Looking back upon this accident we feel that most of our management up to now has been [ ] perhaps too short-term, short-[sighted], and superficial in its nature. … from this point on for the purpose of ascertaining safe flight operations we plan to make long-term plans and spare no resources in [attaining] this final objective of flight safety. Accordingly, we will adjust our management systems and invest all the more heavily into training and program development.[78]

In a March 26, 1998, letter, however, Korean Air requested that the Safety Board remove the Deputy Director of Flight Operations' statement from the public hearing record. In its letter, Korean Air maintained that the deputy director's statement was "personal in nature" and "made in accordance with the Korean custom to express condolences on public occasions to those affected by an accident." The letter also said that "the statement could suggest a finding by [Korean Air] of management deficiencies having been ascertained as a result of internal review" and that "there has been no such finding or review." Further, the letter expressed Korean Air's belief that the company's management structure "is competent to perform its functions." The Safety Board did not delete the statement from the record.

According to the KCAB, Korean Air's president resigned in April 1999 as a result of government criticism. The vice president of Korean Air was subsequently promoted to president and chief executive officer.

1.17.1 Korean Air Postaccident Safety Initiatives

On October 9, 1998, the MOCT ordered Korean Air to suspend 138 flights per week on 10 of its domestic routes for 6 months. According to the MOCT, the action followed seven accidents/ incidents (including the August 5 and September 30, 1998, events listed in section 1.17.5.2). The MOCT ordered the airline to reduce service on its Seoul to Tokyo route from 28 to 26 flights per week. According to a KCAB representative, "these accidents/incidents were without human casualties, but we mete out the severe punishment as a warning." The KCAB indicated that other administrative actions against Korean Air included the following:

- increased captain qualification requirements for large aircraft (including the 747),[79]
- prohibition of initial assignment of large aircraft for first officers,
- increased simulator training for CRM and line-oriented flight training (LOFT), and
- special simulator training for adverse weather conditions.

After the MOCT took action, Korean Air announced that it planned to spend more than $100 million over the next 2 years on safety initiatives, including changes in pilot training and maintenance operations. Korean Air also stated that it planned to accomplish the following:

- install enhanced GPWS on all new aircraft and upgrade traffic alert and collision avoidance systems (TCAS) on all airplanes;
- recruit safety specialists to provide safety awareness training to all flight crewmembers;
- conduct regular aircraft-specific safety and training sessions for flight crews, including an expanded controlled flight into terrain (CFIT) awareness program in both initial and upgrade training;
- develop a "safety alert system" in which data about incidents, accidents, and irregular operations are gathered from every department and analyzed to identify trends and develop accident prevention strategies;
- revise simulator scenarios that reflect a variety of situations that may be encountered during line operations, including takeoffs and landings from different airports, TCAS avoidance maneuvers, and ground proximity escape maneuvers;
- standardize pilot callouts, improve takeoff, approach, and landing checklists, and enhance pilots' knowledge of local terrain; and
- ensure that all flight crewmembers receive CRM and LOFT classes that require "efficient and effective communication in the cockpit and cabin through simulated situations."

Korean Air also indicated that it planned to mandate a 30-day English language training course and implement a confidential pilot reporting system so that errors and concerns can be reported to the chief pilot without fear of reprisal. In addition, the airline implemented a "maintenance error decision air program" designed to detect potential maintenance anomalies caused by human error.

In May 1999, Korean Air's new president issued a safety policy statement and additional material to support the company's planned safety enhancements. Specifically, Korean Air reevaluated its operational philosophy and adopted a five-point "Immediate Action Plan," which contained safety measures that were designed to "minimize exposure to risk, eliminate known hazards, and curtail operations under circumstances where there may be reduced margins of safety."

First, the Immediate Action Plan imposed operational limits at five airports in Korea to minimize exposure to risk when the margin of safety may be reduced. For example, at three of the five airports, no operations can be conducted at night when the runways are wet or crosswinds exceed 15 knots. Second, the plan contained Korean Air's revised policies and procedures for operations under slippery runway conditions[80] and the use of automation.[81] Third, the plan included Korean Air's decision to outsource flight simulator training.[82]

Fourth, the Immediate Action Plan stated that Korean Air's most important operating priority is safety. According to Korean Air, every company line captain participated in a series of seminars in April 1999 in which the captain's decision-making, authority, and responsibilities were redefined. These seminars reemphasized that the captain "serves as the first, and last, line of quality assurance for [Korean Air], and is charged with final responsibility for the safety of its flight operations."

Last, the plan provided senior management's commitment to enhance decision-making, especially as it relates to flight safety matters. The plan stated that Korean Air created an Executive Action Council to resolve critical operational and support issues in a timely manner and a Flight Operations Action Team to identify and resolve critical flight operations issues.

According to Korean Air, new flight crew work rules will become effective in October 1999. The new rules are expected to be similar to the duty and rest standards established under 14 CFR Part 121 and the practices of leading airlines in the industry. Korean Air indicated that its goal was to eventually achieve a standard of 80 hours of flying time per month. Also, Korean Air stated that it was in the process of implementing an automated flight crew scheduling system purchased from Sabre Technologies. This new system was designed to monitor crew training and instrument and landing currency and automatically update compliance with flight and duty limitations. The system was expected to be fully implemented by the end of 1999.

In addition, Korean Air indicated that it has been revising its Flight Operations Manual, Aircraft Operating Manual for each aircraft type, Operations Data Manual, and Aircraft Restriction Manual from the manufacturer-supplied versions to reflect the company's standard operating procedures and achieve standardization. According to Korean Air, 8 of the total 21 chapters of the Flight Operations Manual were revised and distributed to all flight crewmembers on August 1, 1999, and the rest of the chapters were expected to be revised and distributed during October 1999. Korean Air also indicated that all of the company's Aircraft Operating Manuals had been revised and issued according to each aircraft manufacturer's schedule. A Korean Air representative said in September 1999 that the Boeing 747 operating manual had been revised four times since the flight 801 accident.

1.17.2 Korean Air Flight Crew Training

Flight crew training is currently conducted at one of two facilities in Korea. Ground instruction is conducted at the Korean Air Flightcrew Training Center in Seoul, and simulator flight training is conducted at the Korean Air Simulator Flight Training Facility in Inchon. (Korean Air conducts its ab-initio training at the Sierra Academy of Aeronautics in Livermore, California, and then at its Cheju flight training facility.) To become qualified as a Korean Air flight instructor or evaluator, candidates must attend 1 week of ground school, 10 days of simulator observations, 10 days of practice simulator instruction, CRM and LOFT seminars, and check rides. Program managers and senior flight instructors provide supervision and ensure standardization.

1.17.2.1 Basic and Advanced Instrument Flight Course

Korean Air provides basic and advanced instrument flight courses for every specific airplane training program. Pilots receive this training before their initial training on the particular airplane for which they are qualifying. Because the captain of the accident flight was initially trained on the Boeing 727, he took the 727 basic and advanced instrument flight courses; likewise, because the first officer was initially trained on the Boeing 747, he took the 747 basic and advanced instrument flight courses. (The captain received training on the 747 in transition courses, which are discussed in section 1.17.2.2.) According to Korean Air's flight training curriculum at the time of the accident, the basic instrument course consisted of eight 4-hour simulator periods and included modules in air work and instrument departures, arrivals, and approaches. The advanced instrument course, which expanded on the procedures taught during the basic course, included avionics operation, standard instrument departures, noise abatement procedures, standard terminal arrivals (STAR),[83] and engine-out procedures. The advanced course consisted of 10 4-hour simulator periods. The countdown/count up DME/localizer procedure, such as the one depicted in the Guam ILS runway 6L localizer-only (glideslope out) approach, was not included in any of the Korean Air simulator training scenarios for either the basic or advanced instrument courses.

1.17.2.2 Boeing 747 Flight Crew Training

Korean Air's Boeing 747 flight crew training includes initial and transition training, which are presented in five units: ground school, cockpit procedures training, simulator flight training, airplane local training (as required), and route training. The captain and the flight engineer on the accident flight were trained according to the 747 transition training syllabus, and the first officer was trained according to the initial training syllabus.

At the time of the accident, the 747 initial and transition ground school training included instruction on general aircraft systems, normal procedures, abnormal and emergency procedures, weight and balance, performance, limitations, differences, Category II instrument approaches,[84] a review period, and a test. The initial ground school training syllabus allocated 177 hours of instruction for both pilots and flight engineers and required about 28 hours of cockpit procedures training. The transition ground school syllabus allocated about 153 hours of instruction for captains and first officers with type ratings on other airplanes and about 157 hours for flight engineers with qualifications on other airplanes. Pilots and flight engineers were required to complete about 24 hours of cockpit procedures training.

Flight training for the initial and transition courses included 40 hours of simulator time (10 4-hour training periods in which each pilot performed as a PF and a PNF for 2 hours) and a 2-hour proficiency check period. At the time of the accident, the Korean Air simulator training syllabus for 747-100, -200, and -300 initial and transition training consisted of 10 profiles that described the events to be accomplished during each training period. Each profile listed the approaches to be performed, including the specific airport, runway, weather, and airplane malfunction, and information on whether the approach would be made to a landing or the reason for a missed approach or go-around. The 10 training profiles consisted of the following approach scenarios:

- 23 ILS approaches to runway 14 at Kimpo Airport;
- 5 VOR and VOR/DME approaches to runway 32 at Kimpo Airport;

- 2 NDB approaches, one to a runway at Cheju Airport and one to a runway at another airport; and

- 1 localizer (LOC) approach to runway 14 at Kimpo Airport.

After accomplishing the 10 simulator training profiles, pilots were given a proficiency check using the scenarios contained in the 11th simulator profile. Korean Air training records indicated that the 11th simulator profile consisted of four ILS approaches to runway 14 at Kimpo Airport and one VOR/DME approach to runway 32 at Kimpo.

The 747-200 Simulator Training Guide for Instructors, dated February 1997, detailed the various training scenarios used in 747-100, -200, and -300 simulator training at the time of the accident.[85] The training guide described only one of the nonprecision approaches: the VOR/DME approach to runway 32 at Kimpo Airport. The description for this approach included the DME distance to initiate gear and flap configuration changes and specific vertical speed settings during step-down fixes on the approach procedure. Also, this nonprecision approach scenario always involved DME that was located on the airport and colocated and frequency paired with the primary approach navigational facility. Thus, all simulator approach scenarios using DME were approaches for which the pilot had to count down toward the MAP.

The simulator training curricula did not contain nonprecision approaches to other airports or with varied or diverse scenarios. For example, no approach scenarios required the pilot to count down to the DME, fly past the DME, and count up to the MAP, which was required for the runway 6L ILS localizer-only (glideslope out) approach to Guam. At the Safety Board's public hearing, Korean Air's Director of Academic Flight Training and a Korean Air check airman testified that the simulator scenarios were to be followed as published in the training curricula. They also indicated that there were no provisions or guidance that enabled instructors to vary the nonprecision approach scenarios from those published.

The Korean Air Simulator Training Guide contained specific approach scenarios to be used during proficiency checks and type rating simulator checks. These approach scenarios were the same ones taught and practiced during the initial and transition training sessions.

After the accident and subsequent discussions with the Safety Board, the KCAB asked Korean Air to modify its simulator training syllabus to include diverse approaches. The Safety Board notes that the Korean Air simulator training now incorporates a variety of approach scenarios, including approaches in which the DME is not colocated with an on-airport navigational facility and approaches involving countdown/count up DME procedures. Also, the simulator training now includes approaches that are likely to be encountered during domestic and international line operations.

1.17.2.3 Crew Resource Management Program

The Korean Air Director of Academic Flight Training stated that the company instituted a CRM training program in December 1986 as a result of the Korean Air shoot down accident in August 1983 off the coast of the Soviet Union. The director stated that the CRM sessions are not graded and that no program records are kept. Pilots are evaluated on CRM during route checks and proficiency check rides. In addition, pilots receive LOFT[86] during simulator sessions once a year and are evaluated based on how they interact in coping with various anomalies during the simulated flight. According to Korean Air, a total of 1,614 flight crewmembers had successfully completed CRM training classes as of May 1999.

The CRM program that was in place at the time of the flight 801 accident was developed from the United Airlines CRM program and adapted with the assistance of an outside contractor. This 4-day program, which was provided to flight crews only, emphasized dilemma resolution and focused on teamwork and leadership in problem-solving at the individual, crew complement, and organizational levels. The CRM program used reading materials, films, and class exercises to help flight crewmembers recognize and improve aspects of their behavior and interaction. The Director of Academic Flight Training testified that this CRM program taught first officers and flight engineers to intervene and challenge the captain if they had safety or operational concerns. He noted that the company had encountered difficulties teaching some first officers and flight engineers to challenge the captain and intervene in safety-of-flight situations. The director also testified that this issue was no longer a problem in training and that captains were being taught to encourage a cockpit environment in which first officers and flight engineers could freely express concerns when necessary.

In May 1999, Korean Air announced it would replace the existing CRM program with a new CRM program that was developed with and adopted from Delta Air Lines. The new program will consist of four courses: a base course, a course for new captains, a recurrent course, and a recurrent joint flight operations/cabin services course.[87] The one-time base course, called "Error Management CRM," will last 5 days: the first 3 days will be classroom instruction, the fourth day will be a jumpseat observation flight, and the fifth day will be a debriefing session. The one-time "In-Command" course for new captains will last 1 day. The 1-hour pilot recurrent course and the 3-hour recurrent joint flight operations/cabin services course will be presented each year. According to Korean Air, the courses will be taught through lectures, class exercises, reading material, and other techniques to impart practical skills for the crews. In addition, Korean Air stated that its new CRM course would add "realism" to training through an audio-visual presentation format. Korean Air indicated that it expected to implement this program by January 2000.

1.17.2.4 Postaccident Changes to Flight Training

In addition to the changes being implemented in response to the MOCT action and as part of the Immediate Action Plan and the new CRM program, Korean Air indicated that it has made other changes in the area of flight training. For example, the company's Flight Standards Branch, within the Flight Operations Department, is now primarily responsible for overall quality assurance for all flight training and checking activities. Other changes are as follows:

- Beginning in November 1998, training modules on risk and error management and recovery training for CFIT awareness, GPWS and windshear warnings, slippery runways, and crosswind and icing conditions were added to the recurrent proficiency training curriculum for all airplane types.

- In January 1999, a policy of training to proficiency in the recurrent training and checking system was implemented. Crewmembers are to be given three opportunities during recurrent training and checks to receive additional instruction and correction while training to the acceptable level of proficiency.

- Also in January 1999, the Flight Operations Department changed its system for selecting candidates for aircraft transition and upgrade to incorporate "more objective" criteria. The standards for upgrading to captain were also revised. The new standards increase the minimum requirements from 3 years and 3,000 hours to 5 years, 4,000 hours, and 350 landing cycles with the company regardless of previous military or other aviation experience.

- In April 1999, new standardized flight instruction manuals were issued.

- A new Line Check Pilot Manual was being developed to include detailed procedures and requirements so that check pilots could consistently apply and enforce company standards and policies. The new manual was expected to be completed in October 1999.

- The Flight Operations Department developed a new all-volunteer system, to replace the previous assignment system, for all line check pilots. Candidates who volunteer for these positions are to be selected based on their ability to judge deficiencies in training and impart line flying skills. Also, the training requirements for line check pilots were increased so that the check pilots could impart better decision-making and crew coordination skills to the line pilots.

1.17.3 Korean Air Preflight Procedures

The Korean Air Operations Manual that was in effect at the time of the accident (dated May 21, 1997) stated that crewmembers were to arrive at the company dispatch center at least 1 1/2 hours before the scheduled departure time for international flights. According to company procedures at the time, flight crewmembers were to receive their paperwork and then gather as a group to study the paperwork. This process, referred to as the "self-briefing," typically lasted about 15 minutes. The flight crewmembers then met with their assigned SOF for the "SOF briefing." Afterward, the captain met with the flight and cabin crewmembers for a "full crew briefing."

Korean Air stated that, in March 1999, it began issuing "flight-specific manual packages" to outbound crews to ensure that pilots possessed updated route information for each trip. In addition, the company said that it developed an airport information program to promote additional route and airport familiarization. Korean Air expected that this program would be completed by the end of 1999 and that it would cover all of the airports serviced by the company's aircraft.

1.17.3.1 Supervisor of Flying Program

According to Korean Air officials, the company's SOF program began in 1996. The officials described the SOFs as retired captains and instructors who were among the company's most experienced pilots and had no record of disciplinary action. The officials stated that the purpose of the SOF briefing was to ensure that pilots had reviewed all pertinent materials for the flight, including any NOTAMs. Further, the SOFs were expected to periodically check crewmembers' charts and manuals for currency as well as their airman certificates and passports, which are required documents for international flights. There is no formal checklist of items to be covered in the SOF briefing. The officials stated that the SOF briefings were designed to last 15 minutes but averaged about 10 minutes.

In a postaccident interview with Safety Board investigators, the Korean Air Deputy Director of Flight Operations said that he initiated the SOF program to correct pilot performance deficiencies that were involved in the accident/incident events (see section 1.17.5.1) and violations that the company had been experiencing.[88] Further, the deputy director said that he was not aware of any other air carrier that had a SOF program and that he believed the number of accident/incident events and violations had dramatically declined since the initiation of this program.

The SOF for Korean Air flight 801 was a retired company 747 captain. The SOF stated, in a postaccident interview, that he reviewed the flight data and asked the flight crew about the weather conditions en route to and at Guam. The SOF also stated that he and the flight crew discussed a typhoon and the possibility of en route turbulence and that he recommended maximum use of the weather radar. The SOF further stated that he and the flight crew discussed company notices but did not discuss the NOTAMs pertaining to Guam and the out-of-service glideslope associated with the runway 6L ILS approach.[89] The SOF did not check the flight crew's charts for currency. The SOF said that his main concern was to confirm that the flight crewmembers had "looked at the [trip paperwork] items closely."

1.17.3.2 Airport Familiarization Program

Korean Air stated that, in June 1997, it established an airport familiarization program that used audio-visual presentations (purchased from Japan Airlines) to prepare pilots for operations into designated airports. Korean Air requires that an airport familiarization tape be viewed if the company or the FAA list that airport as a "special airport." Title 14 CFR Section 121.445 defines special airports as those that require a special airport qualification for pilots-in-command because of "surrounding terrain, obstructions, or complex approach or departure procedures."[90] Guam International Airport was not classified by Korean Air or the FAA as a special airport; thus, the accident flight crew was not required to view this familiarization tape. However, Korean Air recommends that pilots view a familiarization video if they have not flown into the destination within the preceding 3 months. The airport videotapes are available to pilots 6 days a week.

The audio-visual presentation for Guam gave a general description of Guam's weather and topography, including Mount Alutom, located near the outer marker, and Mount Macajna, located north of the NIMITZ VOR. The presentation advised pilots that " … when you report airport-in-sight, you will be cleared for a visual approach." Further, the presentation stated that " … you [the pilot] will be radar-vectored to ILS runway 6L … . Normally, you will be guided from over Apra Harbor to the localizer … . You will then perform a visual approach." The presentation highlighted the visual approach, identified visual cues for the approach to runways 6L and 24R, and advised pilots not to fly over a hospital located northwest of the airport.

1.17.4 Korean Air Descent and Approach Procedures

1.17.4.1 Briefing and Checklist Usage

A Korean Air instructor pilot testified at the Safety Board's public hearing that the company required the PF to conduct an approach briefing for every approach and that the briefing was to include the division of crewmember duties during the approach procedures. The instructor pilot stated that, if a pilot receives information that a navigational aid, such as a glideslope, was reported to be unreliable or unusable, Korean Air policy requires the pilot not to use that navigational aid to conduct the approach. The Korean Air 747 checklist booklet contained a landing briefing card (dated September 10, 1996), listing the following required items for a landing (or approach) briefing:[91]

LANDING BRIEFING

1. WEATHER
2. STAR
    - TOD
    - No 1 & No 2 VOR/ADF Courses
    - ALT [altitude] & SPD [speed] Restrictions
    - Arrival Routes
3. USING RUNWAY, TYPE OF APPROACH, AND TRANSITION LEVEL
4. REVIEW OF INSTRUMENT APPROACH PROCEDURES
    - Minimum Safe Altitude
    - Approach Frequency (ILS, VOR, ADF)
    - Approach Course
    - Touch Down Zone Elevation
    - Missed Approach Procedure
    - Holding Procedure
5. CREW ACTION AND CALL OUT
6. PARKING SPOT AND TAXI WAYS

* DOCKING GUIDANCE SYSTEM

7. OTHER ABNORMAL CONFIGURATION AND CONDITION

TIME: BRIEFING SHOULD BE COMPLETED PRIOR TO ARRIVAL OVER TOD

The Korean Air instructor pilot testified that company pilots were taught to include the following items in a nonprecision approach briefing:

- ATIS information, including the weather, expected approach procedure, and field NOTAMs;
- arrival and descent procedure to the IAF;
- runway, type of approach, and type of transition;
- transition level;
- instrument approach procedure in detail;
- airport name and chart number;

- approach plate issue and effective dates;
- minimum safe altitude;
- airport elevation;
- special notes;
- configuration of navigational receivers and how to tune and identify them;
- crew actions and callouts;
- procedure to intercept approach course;
- step-down altitudes and how they were determined;
- MDA and how it was determined;
- MAP;
- parking spot and taxiways; and
- instruction to nonflying crewmembers to call out any abnormalities or deviation from procedures.

Korean Air's checklist philosophy, as described in its Boeing 747 Guidebook,[92] states the following:

> Normal procedures[[93]] for each phase of flight are performed by recall, and the normal checklist is used to ascertain that all the safety items have been accomplished. Each response to the checklist challenge should be preceded by the verification of the present configurations, and the crewmembers should check for conformation. If any disagreements have been found between present configuration and checklist response, corrective actions should be taken first before any further checklist challenge.

The Korean Air Boeing 747 Guidebook states that the "descent checklist" is to be performed while the airplane is descending through 20,000 feet to approximately 18,000 feet (or 1,000 feet above transition level in North America). The guidebook also states that the "approach checklist" is to be performed after a speed reduction to 250 knots and while the airplane is descending through 10,000 feet with its inboard landing lights on and that the "landing checklist" is to be performed when the airplane has been configured for landing.

1.17.4.2 Flight Crew Actions and Callouts During Nonprecision Approaches

A Korean Air simulator instructor testified that the company trained its pilots to utilize the step-down rather than the "constant angle of descent"[94] technique when executing nonprecision approaches. However, the instructor stated that captains were permitted to use the constant angle of descent approach technique under visual conditions provided that they did not descend below the published intermediate step-down altitudes.

The Korean Air simulator instructor also stated that, at the time of the accident, pilots were trained to fly a nonprecision approach with the autopilot either engaged or disengaged. With the autopilot engaged, the PF was instructed to program the autopilot/FD controls, including vertical speed and the altitude select, unless the PF specifically directed the PNF to perform that function. In addition, the PF was instructed to initiate all heading, course, and altitude changes, including the selection of the step-down altitudes, while executing the approach profile. Further, the PNF was instructed to monitor the approach and challenge the PF when necessary.

Korean Air did not provide the Safety Board with any documentation from its operations or training manuals on specific PF and PNF roles and duties taught during ground and simulator training. For approach procedures, the only specified duties for the PNF, as described in Korean Air's Boeing 747 Guidebook and 747 Aircraft Operating Manual (page 04.27.01, dated January 30, 1980), were as follows:

- Position flap lever as directed.
- Prior to crossing the outer marker cross-check all flight and navigation instruments, observe all warning flags retracted and all radios tuned to correct frequencies.
- Position landing gear lever down on command.
- Use windshield wipers and rain repellant as required.
- Check AUTO SPOILERS and AUTO BRAKE DISARM lights.

The Korean Air 747 Aircraft Operating Manual (dated October 1, 1984) described the following conditions and locations and the standard callouts for the PNF (with the flight engineer monitoring) during IFR conditions:

- First positive INWARD motion of localizer bar: "Localizer."
- First positive motion of glide slope bar: "Glide slope."
- Final fix inbound (altimeter, instrument, and flag crosscheck): "Outer Marker/VOR/NDB/etc., Time, ____ Feet, altimeters and instruments crosschecked."
- 1000 and 500 ft above field elevation (altimeter, instrument, and flag crosscheck): "1000/500, altimeters and instruments crosschecked."
- After 500 ft above field elevation: (Call out significant deviations from programmed airspeed, descent, and instrument indications.)

- 100 ft above DH [decision height]/100 ft above MDA: "100 above."

- Reaching DH or MAP: "Minimums, approach/strobe/centerline lights-runway (or no runway).

Korean Air indicated that Standardization Circular 90-07, "747 Standard Callouts" (dated April 1996), described actions and callouts to be made during a nonprecision approach. The Standardization Circular Manual, which was issued to all pilots, contained general and aircraft-specific information. However, the callouts were not included in Korean Air's Boeing 747 Aircraft Operating Manual, company Operations Manual, or 747 Flight Crew Training Manual. Korean Air indicated in July 1999 that its pilots were trained to use the standard callouts during initial simulator training and were checked for the use of these callouts during simulator and line checks. Korean Air also stated that its pilots "always take this document in flight" and that the document is "readily available to pilots." The callouts presented in the standardization circular for the PF, PNF, and flight engineer (F/E) are as follows:[95]

At 20,000~18,000 Feet msl:

PF Initiates Descent Checklist

PNF N/A

F/E Executes Descent Checklist

Approaching Transition Level:

PF Transition Altimeter Reset

PNF Transition Altimeter Reset

F/E Transition Altimeter Reset

At 10,000 Feet msl:

PF Initiates Approach Checklist

PNF Calls "One Zero Thousand"

F/E Executes Approach Checklist

1,000 Feet Above Initial Approach Altitude:

PNF Calls "One Thousand to Initial"

PF Responds to PNF "Roger"

F/E N/A

On Intercepting Heading (Check VOR/NDB Freq. and Inbound Course):

PF Select VOR/LOC Mode

PNF Confirms "Select VOR/LOC Mode'

F/E Monitor Auto Mode and Monitor Instruments

First Positive Inward Motion of Localizer Bar:

PNF "VOR Approach;**" "CDI [course deviation indicator] Alive;" "CDI Capture;" (NDB Approach**)

PF Responds "Roger"

F/E Monitor Auto Mode, Monitor Instruments

**PF Orders flap extension on approach then calls "Command Bug Set"

PNF Responds "Command Bug Reset"

PF Sets Auto Brake and Places Speed Brake Lever

After CDI LOC Bar Moving:

PF Requests "Set Inbound Heading"

PNF Responds "Setting Inbound Heading"

F/E N/A

Leaving Initial Approach Fix (IAF):

PNF States "Leaving IAF (name), Time Check, Altitude"

PF Responds "Roger"

F/E Monitors Altimeter and Altitude Cross Check, Monitor Instruments

Landing Gear Down and Landing Checklist:

PF Calls Gear Down, Flaps Down (incrementally), Requests "Landing Checklist"

PNF Responds to confirm gear position and flap position

F/E Executes Landing Checklist

Over Final Approach Fix (Call "Time" and Push Clock Button):

PF States "Outer Marker/Final Approach Fix"

PNF Responds "Outer Marker/Final Approach Fix, Time, Altimeter, and Instrument Cross-Check"

F/E Monitors Altitude, Attitude and Airspeed

1,000 Feet Above Field Elevation (Altimeter, Instrument & Flag Check):

PNF States "One Thousand"

PF Responds "No Flag, Gear and Flaps"

F/E Responds "No Flag, Gear and Flaps" and Monitors Instruments

On Final Approach — Deviation Call:

> The PNF will call any of the following deviations — Bank 15 degrees at or above, DME & Altitude, CDI Exceeds 1/3 dot, Indicated Airspeed exceeds 10 knots, Below Minimum Altitude, Too High or Low on VASI or PAPI [precision approach path indicator]

100 Feet Above MDA:

PF Looks for Visual Cues

PNF States "One Hundred Above"

F/E Monitors Instruments

At MDA:

PNF States "Minimums"

PF Responds "Roger"

F/E Monitors Instruments

1.17.4.3 Terrain Avoidance Recovery Maneuvers

At the time of the accident, one manual issued to Korean Air flight crewmembers — the company's 747 Aircraft Operating Manual — contained written guidance on when to execute a recovery maneuver to avoid terrain. Under the section entitled "PULL UP/TERRAIN AVOIDANCE," the manual stated:[96]

> The published RECOVERY MANEUVER procedure is immediately accomplished by recall whenever the threat of ground contact exists. Either of the following conditions is regarded as presenting a potential for ground contact:
>
> - Activation of the "PULL UP" warning.
> - Inadvertent windshear encounter or other situations resulting in unacceptable flight path deviations.

Korean Air's 747 Aircraft Operating Manual (page 14.20.02, dated November 2, 1992), required the following procedures for the recovery maneuver:

> Aggressively position the thrust levers forward to ensure maximum thrust is attained, disengage autopilot and autothrottle (as installed), and rotate smoothly at a normal rate toward an initial pitch attitude of 15 degrees.
>
> Do not use flight director commands.
>
> Pitch attitudes in excess of 15 degrees may be required to silence the "PULL UP" warning and/or avoid terrain.
>
> Note: In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit (this may be less than 15 degrees in a severe windshear encounter).
>
> Large thrust increases may result in a nose-up pitching tendency requiring forward column pressure and trim.
>
> Monitor vertical speed and altitude. Do not attempt to change flap or gear position or regain lost airspeed until ground contact is no longer a factor.

1.17.5 Korean Air Accident and Incident History

The Safety Board used data provided by Airclaims Limited [97] to compare Korean Air's safety record with the records of five major U.S.-based airlines and five major Asian-based airlines. The total hull loss records for all of these airlines were calculated for a 10-year period ending December 31, 1998, using two measures of activity or exposure to risk: aircraft flight hours and departures. Airclaims Limited defines a total loss as an aircraft that has been destroyed or for which the estimated repair costs rendered the aircraft a total loss under the terms of the insurance contract. (Airclaims Limited notes that some airplanes that became total losses were repaired and returned to service.) Any total loss that resulted from a deliberate violent act was eliminated from the Board's comparison. The results of the comparison are shown in table 3 [* page 46].

As table 3 indicates, eight of the operators had fewer than one hull loss per 1 million flight hours (All Nippon Airways, Singapore Airlines, Japan Airlines, Northwest Airlines, United Airlines, US Airways, Delta Air Lines, and American Airlines). Asiana Airlines had 1.25 hull losses per 1 million flight hours, Korean Air had 2.38, and China Airlines had 4.59.

Seven operators in the comparison group had fewer that one hull loss per 1 million departures (All Nippon Airways, Japan Airlines, Northwest Airlines, United Airlines, US Airways, Delta Air Lines, and American Airlines). Two operators had between one and two hull losses per 1 million departures (Singapore Airlines and Asiana Airlines). Korean Air Lines had 4.79 hull losses per 1 million departures, and China Airlines had 11.74.

1.17.5.1 1983 to 1997 Accident History

Between 1983 and the time of the flight 801 accident, Korean Air experienced several accidents that were attributed primarily to pilot performance.[98] Some of these accidents resulted in substantive management, operational, and policy changes initiated by the company to correct deficiencies identified by the accident investigations. The following is a brief description of some of these pilot performance accidents:

- On August 31, 1983, Korean Air flight 007, a 747-200B, crashed in the Sea of Japan off Sakhalin Island, Soviet Union, killing 269 people. Although the airplane was intentionally shot down, the

Table 3. Loss totals and rates for the 10-year period ending December 31, 1998, by losses per 1 million departures.

Operator	Losses[a]	Aircraft[b] Hours	Aircraft[b] Departures	Losses per Aircraft[c] Hours	Losses per Aircraft[c] Departures
All Nippon Airways	0	2,751	2,069	0.00	0.00
Japan Airlines	0	3,535	1,396	0.00	0.00
Delta Air Lines	1	15,988	9,614	0.06	0.10
Northwest Airlines	1	10,570	5,598	0.09	0.18
United Airlines	2	16,075	7,273	0.12	0.27
American Airlines	3	18,823	8,607	0.16	0.35
US Airways	6	11,700	8,988	0.51	0.67
Singapore Airlines	1	2,351	598	0.43	1.67
Asiana Airlines	1	803	576	1.25	1.74
Korean Air	6	2,522	1,252	2.38	4.79
China Airlines	5	1,090	426	4.59	11.74

[a] Loss totals include all total hull losses, excluding acts of violence.

[b] Aircraft hours and departures are expressed in thousands.

[c] Loss rates are expressed as accidents per 1 million aircraft hours and 1 million departures.

investigation[99] revealed the flight crew likely made a navigation entry error in the autopilot, causing the airplane to depart from its assigned flightpath without the crew's detection and subsequently enter restricted airspace in the Soviet Union.[100]

- On December 23, 1983, Korean Air flight 084, a Douglas DC-10 on a scheduled cargo flight, collided head on with SouthCentral Air flight 59, a Piper PA-31 on a scheduled commuter flight, on a runway at Anchorage, Alaska, in heavy fog. Three people received serious injuries, and three people received minor injuries. The Safety Board determined that the probable cause of the accident was the failure of the Korean Air pilot to follow accepted procedures during taxi, which caused him to become disoriented while selecting the runway; the failure of the Korean Air pilot to use the compass to confirm his position; and the decision of the Korean Air pilot to take off when he was unsure that the aircraft was positioned on the correct runway.[101]

- On July 27, 1989, a Korean Air McDonnell Douglas DC-10-30 crashed in fog about 1.5 kilometers short of the runway at Tripoli International Airport, Libya, during the execution of a nonprecision approach (in which the ILS was out of service).[102] Of the 199 people on board the airplane, 4 crewmembers and 68 passengers died; 6 people on the ground were also killed. The Libyan Civil Aviation Authority determined that the cause of the accident was improper flight crew coordination likely influenced by fatigue.[103]

- On August 10, 1994, a Korean Air Airbus A300-620R landed long at a high rate of speed and overran the runway at Cheju Airport, Korea, after an apparent misunderstanding between the flight crewmembers as to whether they should continue with landing or abort and execute a go around.[104] All of the 160 airplane occupants survived the crash. The airplane was destroyed. According to Korean Air personnel, both pilots were jailed temporarily, and neither resumed flight service with the company.[105]

1.17.5.2 1998 and 1999 Accident and Incident History

Since the time of the Korean Air flight 801 crash, the company has experienced several accidents and incidents, some of which are detailed below.

- On August 5, 1998, Korean Air flight 8702, a Boeing 747-400, HL7496, skidded off the runway and crashed during a landing roll in heavy rain at Kimpo Airport in Seoul. None of the 16 crewmembers were injured, and 65 of the 379 passengers received minor injuries. The accident caused substantial damage to the airplane. The KCAB's investigation determined that the accident was caused by the captain's misuse of the thrust reverser during the landing roll and his confusion over crosswind conditions.[106]

- On September 30, 1998, Korean Air flight 1603, a McDonnell Douglas MD-82, HL7236, overran a runway at Ulsan Airport, Korea, in heavy rain. None of the 6 crewmembers were injured, and 3 of the 142 passengers received minor injuries. Both engines' fan blades were damaged as a result of the event. The KCAB determined that this event was the result of "high speed over a wet runway."

- On March 15, 1999, Korean Air flight 1533, a McDonnell Douglas MD-83, HL7570, overran a runway at Pohang Airport, Korea, during a second landing attempt and crashed into an embankment. The accident occurred in stormy weather with strong winds. One of the 6 crewmembers and 15 of the 156 passengers were injured. The airplane received substantial damage as a result of the accident. The KCAB determined that the cause of the accident was the flight crew's "poor action" in bad weather (including gusts and variable winds), misuse of the brake and thrust reverser during the landing roll, and lack of decision-making for executing a go-around and stop.[107] In addition, the KCAB believed that the flight crew received poor ground assistance.

- On April 15, 1999, Korean Air flight 6316, a McDonnell Douglas MD-11, HL7373, crashed in a residential area of Shanghai, China, about 6 minutes after takeoff.[108] The two pilots and one mechanic on board the airplane were killed. Additionally, at least 4 people on the ground were killed, and 37 others were injured. The airplane was destroyed by impact forces. The accident is being investigated by the Civil Aviation Administration of China with participation by the Safety Board and the KCAB.

1.17.6 Oversight of Korean Air

1.17.6.1 Korean Civil Aviation Bureau

As previously stated, the KCAB, a division within the MOCT, is responsible for providing oversight of the Korean civil airlines. The Safety Board found that two KCAB operations inspectors were assigned to provide oversight of Korean Air's flight operations at the time of the accident. Neither of these inspectors were type rated in any of the airplanes operated by Korean Air. According to the KCAB, these two inspectors also had oversight duties at Asiana Airlines, another domestic air carrier.

The KCAB stated that, before the flight 801 accident, it performed an annual 7-day safety inspection, quarterly 7-day regional inspections, and random inspections an average of 40 times per year. The KCAB also said that it frequently relied on Korean Air to self-report corrective actions taken in response to KCAB inspections.

During testimony at the Safety Board's public hearing, the Korean Air Director of Academic Flight Training stated that the KCAB approved all company aircraft operations manuals, training manuals, training programs, and flight operations procedures.[109] The official also stated that the KCAB provided direct oversight of Korean Air and its training curricula primarily during the annual safety inspection and two to three random operations inspections each year.

Korean Air's Director of Academic Flight Training also testified that the KCAB conducted almost all type-rating proficiency checks on the company's Fokker F.100 and McDonnell Douglas MD-82 airplanes. However, the official said that type-rating proficiency checks on the other airplanes in Korean Air's fleet, including the 747-200, -300, and -SP, were conducted by company check airmen designated by the KCAB.[110]

Korean Air's Director of Academic Flight Training could not recall any direct surveillance by the KCAB on 747 proficiency checks or training sessions. The Korean Air official indicated that, if company records indicated otherwise, he would forward such information to the Safety Board after he returned to Korea. The Board never received any such information from Korean Air. The KCAB, however, stated that it had written records of such surveillance and that it had given these records to Korean Air.

The Korean Air Director of Safety and Security stated that the KCAB provided oversight for the Korean Air simulator training syllabi during the annual safety inspection. This director further stated that, before the accident, he was not aware of any KCAB written criticisms or required changes to the Korean Air flight training program. The Korean Air Director of Academic Flight Training testified that he could not recall any KCAB written record of recommended or required corrective actions as a result of its inspections before the Guam accident. However, the KCAB stated that it has written records of recommended and required actions from its inspections before the accident.

The KCAB stated that, after the flight 801 accident, it hired five inspectors (three of whom were captains), two examiners, and two technical experts. The KCAB also stated that it hired 14 commercial pilots to provide in-house technical expertise. These pilots, however, are not directly involved in oversight activities. In addition, the KCAB inspectors now assigned to Korean Air are type rated in the Boeing 747-400, and they previously flew 747 Classics (that is, the 747-100, -200, -300, and -SP).

Further, the KCAB indicated that, after the accident, it instituted the following changes regarding its oversight of Korean Air: increased simulator training requirements for adverse weather conditions, risk avoidance, GPWS, and terrain awareness; mandated CFIT prevention concepts in recurrent ground school that are to be practiced in simulator training; diversification of training scenarios, including those airports with approach navigational aids that are not colocated with the field of landing; separate localizer and VOR approach requirements included as training items for nonprecision approaches; and a requirement to choose random profiles for check rides.

1.17.6.1.1 Accident and Incident Investigation Authority

The KCAB's Division of Aviation Safety is responsible for aviation accident and incident investigations.

Paragraph 5.4 in Annex 13 to the Convention on International Civil Aviation (Chicago Convention)[111] specifies in part that "the accident investigation authority shall have independence in the conduct of the investigation and have unrestricted authority over its conduct." Further, on November 21, 1994, the Council of the European Union (EU) adopted a directive that specified that EU Member States would ensure, within 2 years, that aviation accident and serious incident investigations were conducted or supervised by a permanent body or entity that is functionally independent of the national aviation authorities responsible for regulation and oversight of the aviation system. According to EU officials, all EU Member States have complied with this directive or are moving toward full compliance.

1.17.6.2 Federal Aviation Administration

Korean Air was granted authority to operate into U.S. airspace under the provisions of 14 CFR Part 129 and International Civil Aviation Organization (ICAO) Annex 6.[112] The FAA approves operations specifications and assigns a principal operations inspector (POI) to each foreign carrier.[113] The POI assigned to Korean Air at the time of the accident was not qualified in any of the airplanes operated by Korean Air, but no international or FAA provisions require that inspectors be qualified or current in any aircraft operated by the foreign air carrier for which they have responsibility. This POI also provided oversight to six other international air carriers. The POI said that, at the time, it was customary for the FAA to rotate inspectors of foreign air carriers so that each foreign airline was assigned a different inspector every 1 to 2 years.

The POI also said that there was no formal interaction between the KCAB and the FAA regarding oversight of Korean Air. Neither civil aviation authority (CAA) was required to formally or informally exchange reports of inspection activities or safety concerns. The KCAB, however, indicated that it and the FAA have an ongoing exchange of reports on inspection activities, violations, and certificate actions as well as safety concerns.

Further, the POI assigned to Korean Air said that the FAA's oversight role for Part 129 operators was to approve operations specifications, inspect trip records and facilities, and accomplish ramp inspections of airplanes and crews when they were in the United States or its territories. The POI also stated that the FAA did not inspect, approve, or provide oversight for a foreign airline's training or operations manuals. The Safety Board has not identified any requirement under the Convention on International Civil Aviation or the Federal Aviation Regulations (FAR) that the FAA be provided copies of these manuals. In addition, the POI stated that the FAA did not conduct line checks or en route inspections on board a foreign carrier.

FAA Order 8400.10, "Air Transportation Operations Inspector's Handbook," volume 2, chapter 4, paragraph 297, states that the purpose of surveillance of each foreign air carrier, its aircraft, and its operations is to determine compliance, on a recurrent or rotating basis, with the FARs and the foreign carrier's operations specifications. According to the FAA order, surveillance is conducted if a foreign carrier experiences "a series of accidents, incidents, violations, or complaints (that relate to safety.)" The surveillance includes any "R" (required) items specified in national program guidelines and can also include routine and unannounced ramp inspections.

Paragraph 297 of the FAA order also states that routine and unannounced ramp inspections of a foreign air carrier conducting operations with foreign-registered aircraft should be limited to those operations being conducted in the United States. The paragraph also states that the inspections should include the following items: aircraft markings; airworthiness, registration, and crewmember certificates; air traffic compliance; taxi and ramp and passenger enplaning/deplaning procedures; baggage and cargo (especially hazardous cargo); and compliance with the pilot-in-command age 60 policy, which states that a flight crewmember is prohibited from acting as pilot-in-command if he or she has reached age 60.

According to the FAA, the only "R" item required for Korean Air is one annual ramp inspection. The FAA indicated that, since 1996, Korean Air received about 201 operations inspections, 129 maintenance inspections, and 48 avionics inspections.

1.17.6.2.1 International Aviation Safety Assessment Program

The FAA established the International Aviation Safety Assessment (IASA) program in August 1992 in response to concerns[114] about the adequacy of surveillance provided to foreign air carriers.[115] According to an overview of the program posted on the FAA's Web site, the IASA is a foreign assessment program that "focuses on a country's ability, not the [ability of an] individual air carrier, to adhere to international standards and recommended practices for aircraft operations and maintenance established by [ICAO]." The overview indicated that "[t]he purpose of the IASA is to ensure that all foreign air carriers that operate to or from the United States are properly licensed and [are provided] safety oversight [ ] by a competent Civil Aviation Authority (CAA) in accordance with ICAO standards."[116] According to the overview:

> A foreign air carrier of a sovereign state desiring to conduct foreign air transportation operations into the United States files an application with the DOT [Department of Transportation] for a foreign air carrier permit under the Federal Aviation Act, … at 49 U.S.C. 41302 … . Consistent with international law, certain safety requirements for operations into the United States are prescribed by the FAA's Part 129 regulations (14 CFR part 129). 14 CFR Part 129 specifies that the carrier must meet the safety standards contained in Part 1

(International Commercial Air Transport) of Annex 6 (Operations of Aircraft) to the Convention on International Civil Aviation (Chicago Convention). Before DOT issues a foreign air carrier permit, it notifies the FAA of the application and requests the FAA's evaluation of the respective CAA's capability for providing safety certification and continuing oversight for its international carriers.

Upon DOT notification of a pending foreign air carrier application, if the FAA has not made a positive assessment of that countr[y']s safety oversight capabilities, the FAA Flight Standards Service will direct its appropriate international field office to schedule an FAA assessment visit to the CAA of the applicant's country. Once the assessments visits have been completed, the FAA assessment team will return to the United States to compile the findings. Appropriate notifications to the CAA and other U.S. Government officials of the results of the assessments will be made from Washington, D.C., headquarters as soon as possible.

If a CAA is found to be meeting its minimum safety obligations under the Chicago Convention, the FAA will forward a positive recommendation to DOT. If there is a pending foreign carrier application, DOT will issue the requested economic authority and FAA will issue operations specifications to permit the carrier to begin operations to or from the United States.

When CAA's of countries with existing air carrier service to the U.S. are found to not meet ICAO standards, the FAA formally requests consultations with the CAA. The purpose of consultations is to discuss [the FAA's] findings in some detail and explore means to quickly rectify shortcomings found with regard to ICAO annexes, to enable its air carriers to continue service to the United States. During the consultation phase, foreign air carrier operations from that country into the United States will be frozen at existing levels. [117] FAA may also heighten its surveillance inspections (ramp checks) on these carriers while they are in the United States. If the deficiencies noted during consultations cannot be successfully corrected within a reasonable period of time, FAA will notify DOT that carriers from that country do not have an acceptable level of safety oversight and will recommend that DOT revoke or suspend its carriers economic operating authority.

When CAA's of countries with no existing air carrier service to the United States are found to not meet ICAO standards, the FAA does not, of course, undertake consultations. The FAA will notify DOT that the CAA does not have an acceptable level of safety oversight and its application for economic authority will be denied. The FAA will undertake a reassessment of the CAA after evidence of compliance with ICAO provisions has been received. FAA will, of course, be willing to meet with CAA's at any time, as [ ] resources permit.

After the assessment visit, consultations (if necessary), and notifications have been completed, the FAA will publicly release the results of these assessments.

The FAA plans to periodically revisit CAA's of countries with air carriers operating into the United States to maintain full familiarity of the methods of that country's continued compliance with ICAO provisions. The FAA may also find it necessary to reassess a CAA at any time if it has reason to believe that minimum ICAO standards are not being met.

DESIRED OUTCOME: The FAA is working to determine that each country meets its obligations under ICAO and to provide proper oversight to each air carrier operating into the U.S. The continued application of this program will result in a lower number of safety-related problems, including accidents, incidents, and an improved level of safety to the flying public.

The FAA established three ratings for the status of countries at the time of the assessment. These categories and their definitions are as follows:

- Category I — Does Comply with ICAO Standards: A country's civil aviation authority has been assessed by FAA inspectors and has been found to license and oversee air carriers in accordance with ICAO aviation safety standards.

- Category II — Conditional: A country's civil aviation authority in which FAA inspectors found areas that **did not meet ICAO aviation safety standards** and the FAA is negotiating actively with the authority to implement corrective measures. During these negotiations, limited operations by this country's air carriers to the U.S. are permitted under heightened FAA operations inspections and surveillance.

- Category III — Does Not Comply with ICAO Standards: A country's civil aviation authority found **not to meet ICAO standards** for aviation oversight. Unacceptable ratings apply if the civil aviation authority has not developed or implemented laws or regulations in accordance with ICAO standards; if it lacks the technical expertise or resources to license or oversee civil aviation; if it lacks the flight operations capability to certify, oversee and enforce air carrier operations requirements; if it lacks the aircraft maintenance capability to certify, oversee and enforce air carrier maintenance requirements; or if it lacks appropriately trained inspector personnel required by ICAO standards. Operations to the U.S. by a carrier from a country that has received a Category III rating

> are not permitted unless they arrange to have their flights conducted with a duly authorized and properly supervised foreign air carrier appropriately certified from a country meeting international aviation safety standards.

During a June 17, 1999, briefing to Safety Board staff, the FAA indicated that, although the IASA program is intended to determine whether a foreign country's CAA is providing adequate oversight, the program does not directly assess whether foreign carriers are receiving such oversight or are complying with the provisions of Annex 6 to the Convention on International Civil Aviation. The FAA assessment team does not conduct surveillance of foreign air carriers; rather, it collects information and evaluates a foreign CAA's compliance with Annex 6 standards in seven areas: aviation law; aviation regulations; CAA structure; technical inspector workforce; technical guidance; records of certification; and records of surveillance, including followup and corrective actions.[118] The country must be found to meet ICAO Annex 6 standards in all seven areas to be rated as Category I. The FAA offers assistance to those countries that, according to its evaluation, do not comply with ICAO Annex 6.

The FAA also indicated that it has completed all of its initial assessments and that the IASA program would soon transition to "Phase 2,"[119] which will focus on review and validation of the initial ratings and continued evaluation of the safety compliance capability of foreign CAAs. According to the FAA, Phase 2 will be accomplished by reviewing each country's rating and all available information relevant to ICAO safety oversight requirements at least every 2 years. However, the FAA indicated that it would reevaluate a country that has air carriers operating into the United States any time there is reason to question whether that country is meeting its international safety oversight obligations.

According to the FAA, Phase 2 rating decisions will be based on information gathered by the FAA, either during an on-site visit or through a questionnaire directed to the foreign CAA, or the results of an assessment by another qualified entity, such as ICAO. Also, the FAA intends to eliminate the Category III rating as part of Phase 2; accordingly, countries found not to comply with ICAO Annex 6 will be rated as Category II regardless of whether that country is conducting operations into the United States.

The KCAB was initially assessed in 1996 and was given a Category I rating. As of October 1999, the KCAB had not been reassessed.

1.17.6.3 Department of Transportation Audit Report on Aviation Safety Under International Code Share Agreements

On September 30, 1999, the Department of Transportation Office of Inspector General (DOT/IG) issued a report, titled *Aviation Safety Under International Code Share Agreements* (Report No. AV-1999-138). The report noted that the number of international code share agreements has more than tripled in the last 5 years and that U.S. carriers are increasingly entering into such agreements with carriers from regions of the world where aviation oversight and safety records are not as strong as those of the United States. The report found that the current process by which code share agreements are approved by the DOT does not adequately address safety implications and that the "FAA has not taken an active role in the approval or safety oversight of international code share agreements, either before or after approval." Specifically, the DOT/IG report stated:

> FAA limits its input to advising [the Office of the Secretary of Transportation (OST)] about whether a foreign carrier's homeland, as distinguished from the air carrier involved, has procedures to exercise oversight of its carriers in compliance with international safety standards. FAA staff stated that if they become aware of adverse safety information about a foreign carrier, they will pass that on as well; however, they were able to provide only one example of this kind of advice, and the effort made to assess safety implications appears to be nonexistent.
>
> [The DOT/IG's] review found that the Department's current procedures require nothing of the U.S. or foreign carrier that will be parties to the agreement about the foreign carrier's safety. FAA performs no trend or other analysis, and makes no recommendations to OST, as to whether it is satisfied that there are no negative safety implications relative to the foreign carrier that will be involved in the code share agreement … .

The DOT/IG's report evaluated the FAA's explanation for its limited oversight role in code share agreements. The report made the following three points:

> First, FAA says it is without legal authority to make safety fitness determinations regarding individual foreign carriers. This view has merit. However, the legal situation is quite different when, as here, a U.S. carrier seeks U.S. approval to hold out to the public flights on a foreign aircraft as if they were U.S. flights and to ticket such flights in the name of a U.S. carrier. Furthermore, Federal law requires that "safety" be a paramount consideration in deciding whether to approve agreements like code shares.
>
> Second, FAA correctly points out that it does make determinations [through the IASA program] about the civil aviation authority in the foreign carrier's homeland. This program identifies whether the carrier's homeland provides adequate aviation oversight of its carriers, and has improved international aviation safety by helping foreign civil aviation authorities improve their oversight. However, this is quite different from a judgment about

the safety practices of an individual carrier. FAA is itself a civil aviation authority that meets international standards, but that is materially different from a conclusion that all U.S. carriers therefore follow sound safety practices.

The third and most legitimate point FAA raises is that it has limited resources and already is resource-constrained in exercising oversight of U.S. aircraft and U.S. crew operations. Adding code share agreements to the workload would be an additional burden and raise expectations. We believe the answer to this is that U.S. carriers seeking approval for a code share agreement can reasonably be expected to perform most of the work and provide FAA assurances that the foreign carrier that will operate as a U.S. flight is compliant with applicable safety requirements. FAA's role would be to ensure that U.S. carriers have a credible process in place to provide such assurances.

The Department of Defense (DOD) is one of the largest U.S. consumers of air carrier services because of its need to transport military personnel to locations throughout the world. According to the DOT/IG report, DOD's policy has been to use U.S. carriers for this transportation service, and DOD performs a safety review of a U.S. carrier before it can be included on an approved list of authorized military air transport providers. The report also indicated that the U.S. carriers proposed the use of foreign code share carriers for providing military transportation. Because DOD must ensure the safety of foreign code share carriers, it established a program in August 1999 with the Air Transport Association and six U.S. airlines.[120] Under this program, the six U.S. air carriers will perform (or will arrange to have a third party perform) safety assessments of their foreign code share partners to ensure that those partners meet the legal criteria necessary to transport U.S. military personnel. The DOT/IG found that the FAA could build on DOD's program and that the FAA must ensure that safety is "a condition of initial and continued approval for international code share arrangements."

The DOT/IG report made the following recommendations to the DOT and the FAA:

- Develop and implement procedures requiring that all U.S. carriers perform safety assessments of foreign carriers as a condition of code share approval and continued authorization. These procedures should include requirements that carriers:
  - perform an initial on-site review of all existing, pending, and future code share partners;
  - establish review procedures, to be approved by FAA, that will address the content of the assessments and qualifications of staff conducting the assessments;
  - develop assessment processes that include review and verification that foreign partners have implemented effective procedures in critical safety areas such as maintenance operations, airworthiness of aircraft, crew qualifications, crew training, flight operations, en-route procedures, emergency response plans, security, and dangerous goods;
  - provide copies of safety assessments to FAA for review and acceptance, and make available to FAA, when necessary, information supporting assessment results;
  - submit confirmations from senior safety officials that the assessment results were satisfactory and any deficiencies noted have been corrected; and
  - coordinate reviews to avoid multiple assessments of foreign carriers code sharing with more than one U.S. partner.
- Coordinate closely with the Department of Defense to maximize the effective use of limited resources between the two agencies, avoid duplication, and establish protocols for the exchange of information about carrier safety assessments. FAA should also consider the safety assessment results in performing IASA reviews.
- Establish procedures for terminating or restricting the use of code share agreements when (1) the Department of Defense determines that adverse safety information warrants prohibiting U.S. military personnel from using a foreign carrier, (2) the U.S. carrier terminates the agreement, or (3) FAA, on its own initiative, makes a similar determination regarding the transport of U.S. passengers.

The DOT/IG report also recommended that the FAA

- Develop oversight procedures for FAA to validate U.S. carriers' safety assessment programs. The validation should include:
  - reviews of air carriers' audit procedures, assessment processes, and documentation supporting review conclusions to ensure the consistency, quality, and effectiveness of the review results;
  - comprehensive audits of a sample of safety assessments to confirm that carriers have applied agreed upon standards and procedures in conducting the assessments; and
  - procedures to, if necessary, perform on-site inspection of aircraft used in code share operations.

- Require that FAA staff perform risk assessments using available safety data on foreign carriers and review results of air carrier safety assessments, if made available, as part of its safety advice to OST on code share applications. This interim procedure should be used no more than 3 months, until the Department finalizes new code share procedures.[121]

1.18 Additional Information

1.18.1 Minimum Safe Altitude Warning System

1.18.1.1 Postaccident Actions Taken by the Federal Aviation Administration

On August 15, 1997, the FAA announced in a press release that, as a "routine precaution," it had ordered MSAW testing and recertification after the Safety Board's investigation of the flight 801 accident raised questions about the MSAW's performance. The FAA reported that, of the 192 in-service[122] MSAW software functions at radar approach control facilities, all but 2 were found to be working properly. According to the press release, the software functions were corrected, and all of the functions were recertified as operating properly.

Also, in response to inquiries from Safety Board staff, the FAA created special teams of automation experts to completely examine all site adaptation parameters for the 192 MSAW systems located throughout the United States. The FAA directed ATC managers at these locations to document and report any MSAW problems.

Further, the FAA's Associate Administrator for Air Traffic Services directed a fact-finding review of MSAW equipment and operational procedures at 10 ATC towers The review included a survey of 105 air traffic personnel and 33 airway facilities personnel.

According to the FAA's executive summary of the MSAW fact-finding review (dated September 1997), "air traffic staff and operational personnel, except for those with automation training, claimed little knowledge of the parameters or components that make up MSAW." The executive summary indicated that very few of the air traffic survey respondents could remember receiving facility training about different MSAW areas and that most reported that their only MSAW training was an overview during the initial air traffic course.

According to the executive summary, the air traffic survey respondents indicated that a check of the MSAW aural alarm was required at the beginning of each shift, but they gave varying answers concerning what should be done if the MSAW was not functioning properly. Likewise, these survey participants believed that controllers should issue an advisory if an aircraft generates an MSAW alert, but the participants were not consistent in their answers regarding who was responsible for responding to the MSAW alert at a satellite tower. In addition, the air traffic personnel in the survey gave different answers regarding who had the authority to adjust MSAW parameters and "vague" answers regarding MSAW general notices.

All of the airways facilities personnel in the survey indicated that daily functional checks of aural MSAW alarms were required, and they knew where this check was documented. However, these personnel gave varying answers concerning how they would complete the check if an MSAW system were inhibited. Further, these respondents indicated that their MSAW training ranged from initial hardware training and on-the-job training to only on-the-job training for those personnel who completed initial schooling before the MSAW system was implemented.

The fact-finding review also found that the ARTS IIA and IIIE parameter documentation was unclear and confusing to automation specialists and that there were "no guidelines or standards defined in any document concerning the proper way to adapt the MSAW site variables." The survey revealed that, as a result of inadequate reference material, the MSAW altitudes at one ATC tower and two TRACONs were set incorrectly. These facilities had adapted the MSAW approach path monitor altitudes to be agl values when the system was intended to provide msl values. As a result, all the altitudes used for the MSAW system were hundreds of feet too low at the ATC tower and one of the TRACON facilities; the altitude discrepancy at the other TRACON was "negligible" because of its approximate sea level elevation.

On the basis of its fact-finding review, the FAA made several internal recommendations, including the following:

- a standardized comprehensive training program should be established to provide a basis for entry-level and periodic refresher training in the operation and maintenance of MSAW equipment, and a certification process should be established for personnel who have completed this training;
- uniform site adaptation/system parameters should be established for MSAW equipment operation;
- provisions for periodic evaluation of MSAW equipment should be established to ensure system integrity and reliability; and
- configuration management of all software should be reflected in appropriate documents and centrally controlled.

In addition, in an October 1997 briefing to Safety Board investigators, FAA officials presented the agency's planned corrective actions for the national MSAW system. The officials stated that the FAA was developing a central oversight process for the MSAW program and that MSAW systems would be flight checked and ground certified as part of the commissioning process for a new radar and then periodically thereafter. Further, the officials said that the FAA had approved a new MSAW software management policy that "established strict management oversight and control" for MSAW software modifications.

1.18.1.2 Previous Safety Board Recommendations on the Minimum Safe Altitude Warning System

The Safety Board has issued numerous safety recommendations regarding the MSAW system. Recent MSAW safety recommendations have addressed the installation of MSAW equipment in VFR terminal facilities that receive radar information from a host radar control facility (as is the case with the Agana tower), as well as the inspection and testing of MSAW speakers to ensure the integrity of MSAW systems.

Development of an MSAW System (A-73-46)

On December 29, 1972, Eastern Air Lines flight 401, a Lockheed L-1011, N310EA, crashed near Miami, Florida. In its final report,[123] the Safety Board stated that its investigation

> … revealed another instance where the ARTS III system conceivably could have aided the approach controller in his ability to detect an altitude deviation of a transponder-equipped aircraft, analyze the situation, and take timely action … to assist the flight crew. In this instance, the controller, after noticing on his radar that the alphanumeric block representing flight 401 indicated an altitude of 900 feet, immediately queried the flight as to its progress. An immediate positive response from the flight crew, and the knowledge that the ARTS III equipment, at times, indicates incorrect information for up to three scans, led the controller to believe that flight 401 was in no immediate danger.

As a result of its findings, the Safety Board issued Safety Recommendation A-73-46, which asked the FAA to

> Review the ARTS III program for the possible development of procedures to aid flight crews when marked deviations in altitude are noticed by an air traffic controller.

In a May 31, 1977, letter, the FAA advised the Safety Board that an MSAW system had been developed as an integral function of the ARTS III program and that controllers had received guidance on its use. On September 16, 1977, the Safety Board classified Safety Recommendation A-73-46 "Closed — Acceptable Action."

Minimizing MSAW Inhibited Areas (A-90-130)

On September 8, 1989, USAir flight 105, a 737-200, N283AU, struck four electronic transmission cables while executing the localizer backcourse approach to runway 27 at Kansas City International Airport in Kansas City, Missouri.[124] The Safety Board's final report on this incident concluded that, although the Kansas City airport's ATC facility was equipped with MSAW software, the MSAW alert failed to activate during the premature descent of flight 105 because the descent had occurred more than 1 mile from the runway threshold and inside an area that had been designed to inhibit the MSAW to reduce false alerts. The Safety Board's report said that " … this incident indicates the need to revise the parameters controlling the size of the MSAW inhibit areas." The report urged the FAA "to provide site adaptations guidance to encourage modification of MSAW parameters, as appropriate, to increase the MSAW protection areas and to minimize the extent of inhibited areas." On the basis of its findings, the Safety Board issued Safety Recommendation A-90-130, which asked the FAA to

> Provide site adaptation guidance to encourage modification of Minimum Safe Altitude Warning parameters, as appropriate, to minimize the extent of inhibit areas.

In an October 6, 1993, letter, the FAA stated that it had issued a change to FAA Order 7210.3K, "Facility Operation and Administration," which provided for site adaptation guidance to minimize the extent of MSAW inhibited areas. Because the FAA's response met the intent of Safety Recommendation A-90-130, it was classified "Closed — Acceptable Action" on January 28, 1994.

MSAW Site Variables and Capture Boxes (A-94-187)

On June 18, 1994, a Transportes Aereos Ejecutivos, S.A. (TAESA) Learjet 25D, operating under 14 CFR Part 129, was executing an ILS approach in IMC when the airplane crashed 0.8 nm south of the runway 1R threshold at Dulles International Airport, Chantilly, Virginia.[125] The 2 flight crew members and all 10 passengers were killed. The Safety Board's investigation determined that the accident airplane did not generate any MSAW alerts while on the approach to the airport. The investigation also determined that the MSAW site variable parameters at the airport required two "current position" radar returns or three "predicted position" radar returns below the 500-foot floor before the aural and visual alerts would activate. A review of the radar data revealed that the airplane generated one radar return below the alert altitude of the runway 1R MSAW capture box.

The Safety Board's investigation of this accident revealed discrepancies with the airport's MSAW equipment.[126] Specifically, the MSAW site variable parameters for runway

1R indicated a discrepancy between the MSAW-defined runway location and the actual threshold location. The FAA said that, when the ARTS III software was programmed for a 10° west variation (the angular difference between true north and magnetic north at Dulles Airport), the computed position for the runway threshold did not correlate to the actual geographic runway location. Further, the “radar-established” runway position was 700 feet northeast of the actual runway threshold. The Safety Board found that the error in the radar position for the runway 1R threshold resulted in a similar displacement of the radar MSAW capture box from its intended position with the actual approach path to runway 1R. The Safety Board concluded that such displacement might compromise the protective intent of the MSAW system.

On November 21, 1994, the Safety Board issued Safety Recommendation A-94-187, which asked the FAA to

> Conduct a complete national review of all environments using MSAW systems. This review should address all user-defined site variables for the MSAW programs that control general terrain warnings, as well as runway capture boxes, to ensure compliance with prescribed procedures.[127]

In a March 20, 1995, letter, the FAA stated that it planned to review the MSAW site variables to ensure compliance with prescribed procedures. According to the FAA, the review would address all user-defined site variables for the MSAW program that control general terrain warnings, as well as runway capture boxes, to ensure compliance. The FAA stated that its review of 190 ATC facilities (128 operational ARTS IIA and 62 operational ARTS IIIA sites) would begin in April 1995 and be concluded by July 1995. On November 20, 1995, the Safety Board stated its concern that the FAA’s review process for the 190 ATC facilities with MSAW was taking longer than originally anticipated.

On January 26, 1996, the FAA stated that it had completed its review of the 190 ATC facilities. Further, the FAA stated that, as of October 1995, proper alignment of the MSAW capture boxes had been verified at all 128 ARTS IIA and 62 ARTS IIIA sites.[128] On April 8, 1996, the Safety Board stated that, because this action met the intent of Safety Recommendation A-94-187, it was classified “Closed-Acceptable Action.”

MSAW Aural Alerts in VFR Facilities (A-95-120)

On January 29, 1995, a Beechcraft A36 crashed during a missed ILS approach to DeKalb-Peachtree Airport in Chamblee, Georgia.[129] The pilot, the sole occupant of the flight, was killed. The Safety Board determined that, before the accident, the airport tower had received four MSAW general terrain warning alerts from the Atlanta TRACON, which was providing approach control services. The tower was equipped with a D-BRITE radar display with visual MSAW alerting only.[130]

The Safety Board’s investigation found that, if a full MSAW system (including an aural alert) had been installed in the DeKalb-Peachtree tower, the controller would have received an aural MSAW alert along with the visual alert that had been depicted on the radar. Further, the tower controller told Board investigators that he did not observe the visual MSAW alert on the D-BRITE because he had been involved with other duties before the accident that did not allow him to continually monitor the data block for the airplane.

As part of its investigation into the accident, on February 8, 1995, the Safety Board requested that the FAA provide its policy on installation of aural MSAW alerts at low-density ATC towers equipped with D-BRITE radar displays. On June 27, 1995, the FAA stated that “ … no policy exists for the operation of an aural alarm associated with MSAW in VFR towers that are not combined with full radar approach control facilities.”

On November 30, 1995, the Safety Board issued Safety Recommendation A-95-120, which asked the FAA to

> Within 90 days from the receipt of this letter, develop a policy that would require the installation of aural minimum safe altitude warning (MSAW) equipment in those visual flight rules terminal facilities that receive radar information from a host radar control facility and would otherwise receive only a visual MSAW alert.

On February 21, 1996, the FAA stated that it would conduct a cost-benefit analysis to determine the feasibility of implementing this safety recommendation. The FAA further stated that the analysis would be completed by the end of March 1996. In June 1996, the FAA completed the cost-benefit analysis and determined that it was feasible to implement the recommendation. The FAA expected that implementation would be accomplished by the end of March 1997.

In its July 15, 1996, letter to the FAA, the Safety Board stated that, although the FAA’s implementation of the requirement for the aural alert was not accomplished within the 90 days specified in the safety recommendation, the Board was pleased that the FAA had proceeded with the implementation. The Board indicated that it would wait to receive a list of the affected facilities and anticipated installation dates.

On July 31, 1997, the FAA stated that it had conducted a survey to determine the total number of ATC facilities that did not have aural MSAW alerts installed. The FAA found that 43 remote displays had been equipped with aural alarms but that 69 remote displays did not have aural alarms. The FAA anticipated that the aural alarms at those 69 remote displays would be implemented by February 1998.

On December 30, 1997, the Safety Board said that it was encouraged that the FAA was moving forward and urged the FAA to keep the program on track and within its anticipated milestones. On May 14, 1998, the FAA said that, as of April 10, 1998, kits had been delivered to all 69 remote sites and that all alarms would be operational during May 1998. However, at the Safety Board's public hearing in March 1998, the FAA's Deputy Director for Air Traffic Operations testified that the new projected completion date for installation of aural alarms at VFR towers, including the tower at Guam, was April 2000.

On October 19, 1998, the Safety Board stated that the primary intent of this recommendation was to ensure that VFR tower controllers who have a visual representation from a distant host radar receive an aural alert when aircraft under their control and with whom they are in radio communication descend below the minimum safe altitude. If the tower controller was engaged in visually scanning for other aircraft, the aural alert would allow the controller to determine the aircraft call sign and transmit the appropriate warning to the pilot. The Board's letter indicated that the FAA was unclear about whether controllers at VFR terminal facilities would receive an aural alert for those aircraft with whom they are in communication. Further, Safety Board staff had determined that, in at least one location, the VFR tower would not receive an aural warning. (The Board's letter did not identify the location of this facility.) The Board requested that the FAA ensure that controllers at all VFR towers with visual representation systems from a distant host radar receive an aural alert when aircraft within their traffic pattern and with whom they are in communication descend below the minimum safe altitude. Pending the receipt of this information from the FAA, Safety Recommendation A-95-120 was classified "Open — Acceptable Response."

On September 29, 1999, a representative from the FAA stated that the agency's management had indicated that the Agana tower was currently receiving aural MSAW alerts. At an October 7, 1999, briefing attended by the FAA Administrator, the Safety Board Chairman, and staff from both agencies, the FAA indicated that 69 MSAW aural alarms had been delivered and that 51 alarms were to be delivered. The FAA expected that the acquisition of these 51 alarms would be completed by October 2000 and that their installation in VFR towers would be completed by April 2001.

On October 12, 1999, the FAA Program Director for Serco Aviation Services told Safety Board staff that the Agana tower has the capability to receive an aural MSAW alert but that, unless the Guam CERAP transfers responsibility for the aircraft's data block, the tower will not receive the aural warning. The official added that the CERAP does not currently transfer responsibility for the aircraft's data block to the Agana tower; therefore, the tower does not receive an aural MSAW alert.

On October 14, 1999, the FAA Program Director for Air Traffic Operations confirmed that Agana tower was not receiving aural MSAW alerts. In an October 15, 1999, facsimile, the program director indicated that the Agana tower "has the software and hardware capability in place to receive aural alarms." The director further indicated that the FAA had issued a policy "to ensure that the facility that is in direct radio communications with the aircraft receives the aural alarm" and that the policy would become effective by November 15, 1999. (The FAA subsequently indicated that, under the new procedures, the Guam CERAP would transfer responsibility for the aircraft's data block to the Agana tower and that the aural MSAW alert would be transferred to the tower upon its acceptance of the transfer of the data block. The tower would advise the CERAP after an MSAW alert was issued.) The program director stated, in a followup telephone conversation with the Safety Board's Director of the Office of Aviation Safety, that a national policy would be issued to ensure that procedures similar to those being implemented at Guam are followed at other VFR towers.

On October 25, 1999, the FAA indicated that the MSAW aural alarms for the ARTS IIA system at Guam were reconfigured on October 24, 1999. The FAA stated that, in the event of a low-altitude alert for an aircraft operating in the vicinity of Guam International Airport, aural alarms will be simultaneously generated at the CERAP and the Agana tower, along with visual low-altitude alerts on the radar displays at both facilities.

On November 2, 1999, the Safety Board received a copy of draft FAA Notice N7210.485, "Minimum Safe Altitude Warning for Remote Tower Displays." According to the notice, facility managers at ATC towers that have aural alarms for MSAW are to ensure that "the operational support facility has adapted the software functionality to ensure the aural alarms operate in the ATCT [air traffic control tower]" and that "aural alarms are received in the ATCT upon transfer of communications." The FAA indicated that the effective date for this notice would be February 1, 2000.

The Safety Board's evaluation and classification of Safety Recommendation A-95-120 are discussed in section 2.6.2.

Inspections and Tests of MSAW Speakers and the Standard Terminal Automation Replacement System Program (A-97-22 Through A-97-27)

On October 2, 1996, a Piper PA-32-300, N2881W, crashed in a heavily wooded area in Brandywine, Maryland, while on approach to Washington Executive/Hyde Field Airport in Clinton, Maryland.[131] The pilot and two passengers were killed, and the airplane was destroyed. According to MSAW data retrieved from the Washington National TRACON, the accident airplane generated four general terrain warning MSAW alerts during the approach to the airport. A controller-in-training and a fully certified instructor were providing ATC services to the accident airplane from the TRACON's F-2 radar position. In a postaccident interview, both controllers stated that they did not recall seeing or hearing any MSAW alerts. Several other controllers and a supervisor who were stationed at nearby positions about the time of the accident also stated that they did not recall hearing or observing any low-altitude warnings before the accident.

As part of the Safety Board's investigation of this accident, a Board investigator toured the TRACON radar room to observe the control position that provided ATC services to the accident pilot. During this tour, the investigator noted that the MSAW aural alarm speaker, located directly above the F-2 radar position (and the only MSAW speaker in the radar room), was covered with heavy paper held in place with what appeared to be masking tape.

On the basis of its findings during this accident, the Safety Board issued Safety Recommendations A-97-22 through -27 on April 16, 1997. Safety Recommendations A-97-22 and -23 asked the FAA to

> Immediately issue an urgent general notice to all affected air traffic managers, directing them to conduct an immediate visual inspection and aural test of the aural minimum safe altitude warning speakers in their facilities to ensure that no devices have been placed over them that might hinder, mute, or prevent the aural warning from being heard in the operational quarters. (A-97-22)
>
> Require that a daily visual inspection and aural test of the minimum safe altitude warning (MSAW) speakers located in the operational quarters be conducted by supervisory personnel prior to the start of each shift to ensure the integrity of the MSAW system. Require that these inspections be recorded in the appropriate facility logs. (A-97-23)

On July 1, 1997, the FAA stated that it agreed with the intent of Safety Recommendations A-97-22 and -23. The FAA stated that, on May 7, 1997, it had ordered air traffic division managers to brief facility managers on the issue of muted MSAW speakers and instructed supervisors to conduct a visual inspection of MSAW speakers and remove "any muting devices" from these speakers. In addition, the FAA issued a general notice on June 7, 1997, to implement the requirement for supervisors to check the MSAW speakers as part of the shift checklist and record the completion of this inspection on the appropriate facility logs. The FAA also revised Order 7210.3, "Facility Operation and Administration," to reflect the change in policy and procedures.

On February 27, 1998, the Safety Board stated that, because the actions taken by the FAA addressed the intent of Safety Recommendations A-97-22 and -23, they were classified "Closed — Acceptable Action."

Safety Recommendation A-97-24 asked the FAA to

> Require that all affected terminal personnel be briefed on the contents of this safety recommendation letter. This briefing should focus on generating awareness and vigilance in those situations in which a safety alert might occur and controllers must be prepared to respond, as directed in FAA Order 7110.65, "Air Traffic Control."

On July 1, 1997, the FAA stated that it complied with this safety recommendation in a June 9, 1997, memorandum to facility managers, requiring that controllers be briefed on how to respond to MSAW alerts. The facility managers were directed to ensure, within 2 weeks after the receipt of the memorandum, that all operational personnel were briefed on the requirements of FAA Order 7110.65, "Air Traffic Control," paragraph 2-1-1, "Duty Priority;" 2-1-6, "Safety Alerts;" and 5-15-57, "Inhibiting Minimum Safe Altitude Warnings (MSAW)." All operational personnel were also expected to be briefed on the actions to be taken when controllers are alerted by the MSAW of an aircraft's proximity to terrain.

On February 27, 1998, the Safety Board stated that it had received a copy of the FAA's June 9, 1997, memorandum but that, in light of the Korean Air flight 801 accident on August 6, 1997, the Board had not received written confirmation that the actions directed by the memorandum were completed for the Guam ATC facilities. On September 25, 1998, the FAA stated that it had accomplished the briefing to Guam ATC facility personnel on July 18, 1997. As a result, the Safety Board classified Safety Recommendation A-97-24 "Closed — Acceptable Action" on January 14, 1999.

Safety Recommendation A-97-25 asked the FAA to

> Modify the software for the minimum safe altitude warning system to enhance conspicuity of those aircraft that may require the controller's immediate attention and action. Such modifications might be accomplished by placing the target and data block within a flashing circle.

The FAA stated in its July 1, 1997, letter that it reviewed the feasibility of modifying the software for the MSAW system to enhance the conspicuity of the data block. The FAA concluded that the existing MSAW processing generated sufficient alarms and was completely adequate; thus, no further action would be necessary.

On February 27, 1998, the Safety Board stated that it was disappointed with the FAA's response to this safety recommendation and the FAA's continued belief that the design of the current MSAW visual display is adequate. Further, the Safety Board stated that the evidence in the Brandywine, Maryland, accident clearly demonstrated that multiple MSAW visual and aural warning alerts were generated in the operational quarters of the TRACON but that the controller failed to respond to these alerts. The Safety Board believed that the FAA should reconsider its position not to remedy the deficiencies that led to the issuance of this recommendation.

On September 25, 1998, the FAA stated that color displays, now under development for the Standard Terminal Automation Replacement System (STARS), would provide the increased conspicuity suggested in this safety recommendation. According to the FAA, the STARS early display configuration initial operational capability was scheduled for Ronald Reagan Washington National Airport in March 1999, and the early display configuration operational readiness demonstration was scheduled for June 1999. The early display configuration was to include the color red for alerts in addition to flashing data blocks. All ARTS data, except for alerts, would be monochrome.

On January 14, 1999, the Safety Board stated that, pending the commissioning of STARS and the FAA's inclusion of the flashing red MSAW display feature in the system's final operational configuration, Safety Recommendation A-97-25 was classified "Open — Acceptable Response."

On August 13, 1999, the FAA stated that the delivery of STARS had been delayed. The FAA indicated that, on April 26, 1999, it announced a revised plan for the STARS program. According to the revised plan, the STARS early display configuration (which includes existing MSAW capability) is to begin initial operations at Syracuse, New York, and El Paso, Texas, in December 1999 and January 2000, respectively. Also, the FAA stated that, as part of the revised plan, it would procure ARTS color displays (which display the alert data blocks in flashing red) for the largest TRACONs and any new facilities while STARS development continues. The ARTS color displays are scheduled to begin operations at the New York TRACON in August 2000.

The FAA indicated that, when the STARS full-service system is deployed, the MSAW alerts will flash in red. However, the FAA stated that it did not plan to modify the existing MSAW system as requested in this safety recommendation because the existing system provides both aural and visual alarms and is completely adequate when operated according to design.

On November 3, 1999, the Safety Board stated that it was deeply concerned about the significant delay in fielding STARS and that it could not continue to maintain the classification of this recommendation, which was evaluated to be "Open — Acceptable Response" in January 1999, if the implementation of STARS according to its current schedule was the FAA's only means for complying with the recommendation. The Board urged the FAA to expedite the implementation of STARS by significantly accelerating the current schedule. The Board also urged the FAA to reconsider its position on modifying existing MSAW software if the STARS implementation schedule cannot be accelerated. Pending the FAA's reconsideration of this issue or a change in the implementation schedule for STARS, Safety Recommendation A-97-25 remained classified "Open — Acceptable Response."

Safety Recommendation A-97-26 asked the FAA to

> Require that the Standard Terminal Automation Replacement System program include a minimum safe altitude warning (MSAW) speaker at each radar display, a capability for the controller to momentarily override and mute an MSAW alert, and a computerized recording of the muting of such an alert.

On July 1, 1997, the FAA outlined the specifications for STARS and the MSAW system. On February 27, 1998, the Safety Board stated its belief that, for those aircraft that qualify under the MSAW system as part of the routine ATC services, the controller should not be given the option to permanently inhibit the MSAW processing. The Board clarified the intent of this safety recommendation by restating that the controller should be permitted to temporarily mute an alert to acknowledge that warning was received and then act on such an alert, if required. Further, the Board stated that, although the FAA provided specifications regarding the STARS and MSAW system, it did not address the intent of the recommendation.

On September 25, 1998, the FAA said that STARS terminal controller workstations and tower display workstations contained individual aural alarm speakers and that STARS would permit MSAW alert inhibits for either a specified aircraft or workstation. The FAA also stated that STARS was designed to permit temporary inhibits resulting from specific aircraft operation characteristics or possible system malfunctions and that all inhibit actions would be recorded. According to the FAA, STARS allows a controller to silence a routine aural alert by hitting an "acknowledge" key. The FAA indicated that, although the aural alarm would be silenced, the alert would remain displayed until the violation condition ceased.

On January 14, 1999, the Safety Board stated that, because STARS incorporated all components suggested in Safety Recommendation A-97-26, it was classified "Closed — Acceptable Action."

Safety Recommendation A-97-27 asked the FAA to

> Require, under the Standard Terminal Automation Replacement System program, that minimum safe altitude warning alerts on instrument flight rules aircraft be duplicated at a position in the operational quarters designated for supervisory personnel and that the supervisor determine the validity of the alert and whether appropriate corrective action has been initiated or is required.

The FAA's July 1, 1997, letter indicated that there is no operational requirement under STARS to duplicate MSAW alarms at supervisory positions. The FAA also stated that supervisory positions did not include controller displays and that it did not plan to provide displays to supervisory personnel. According to the FAA, STARS would provide a supervisor with the ability to monitor MSAW alerts immediately from every controller position that displays an alert.

On February 27, 1998, the Safety Board stated its understanding that the current STARS operational documentation contained no requirement to duplicate the MSAW alerts at supervisory positions and that STARS would provide a supervisor with the ability to monitor MSAW alerts immediately from every controller position that displays an alert. The Board explained that it was not the intent of this recommendation to have a controller workstation be designed for the supervisor but rather to enable the supervisor to be "in the loop" if an MSAW alert was generated. The Board believed that such an arrangement would serve as a form of redundancy that could enhance the benefits of the MSAW system and STARS.

In its September 25, 1998, letter, the FAA stated that supervisors should be aware whenever MSAW alerts are generated. Further, the FAA stated that, in STARS, supervisor awareness of MSAW events is accomplished through aural alarms at each controller position. According to the FAA, supervisors are expected to be on the control room floor to monitor all areas of the operation, including MSAW alerts, and are expected to spend a minimal amount of time at supervisory workstations.

On January 14, 1999, the Safety Board stated that the individual aural alert speakers located at each controller position should alert a supervisor to the sector experiencing an MSAW alert. Therefore, supervisors should be able to react to each alert from their workstation or throughout the operating floor. Because the intent of Safety Recommendation A-97-27 was satisfied in an alternative manner, it was classified "Closed — Acceptable Alternate Action."

1.18.2 Traditional and Enhanced Ground Proximity Warning Systems

1.18.2.1 Traditional Ground Proximity Warning System

Traditional GPWS uses numerous input signals to determine if a terrain collision threat exists.[132] Inputs from the aircraft systems include the radio altitude,[133] descent rate and airspeed, landing gear position, landing flap position, and glideslope information. This information generates the visual and aural annunciations to the flight crew.

GPWS uses the radio altimeter to calculate closure rate with terrain to predict a potential collision threat. However, if the terrain rises steeply (for example, a sheer cliff), the system cannot provide a timely warning to the flight crew. The optional altitude callout advisories generated by GPWS are the aircraft's altitude above the ground as calculated by the radio altimeter.

1.18.2.2 Enhanced Ground Proximity Warning System

Enhanced GPWS has the ability to "look ahead" of the aircraft to determine the terrain elevation along the flightpath. Enhanced GPWS can therefore provide pilots with visual and aural alerts in advance of an impending impact with terrain, thus allowing pilots more time than with traditional GPWS to determine the necessary corrective actions to be taken.[134]

Enhanced GPWS compares the aircraft's position, as determined by its on-board navigational systems (that is, the flight management system [FMS], inertial reference system, or GPS), with a stored terrain database. Terrain and ground obstructions that may pose a collision threat along the flightpath of the aircraft result in aural and visual warnings. The visual warning information is provided to the pilot using the color graphics capabilities of a dedicated display screen, the color weather radar, or an Electronic Flight Instrument System map display (depending on the particular installation).

Further, unlike traditional GPWS, enhanced GPWS utilizes an airport position database to establish a "terrain clearance floor" around all airports. This feature ensures sufficient terrain clearance regardless of the airplane's landing gear and flap configuration.

1.18.2.2.1 Notice of Proposed Rulemaking for Enhanced Ground Proximity Warning Systems

On August 26, 1998, the FAA issued a notice of proposed rulemaking (NPRM) addressing the development and installation of a TAWS[135] (Docket No. 29312, Notice No. 98-11). The NPRM stated that Technical Standard Order (TSO) C151, titled "Terrain Awareness and Warning System," was being developed through the FAA's TSO process and that, once the TSO has been completed, the FAA would issue an advisory circular (AC)[136] addressing an acceptable means of obtaining installation approval.

The FAA believed that the installation of a TAWS would ensure that all applicable airplanes operated under Parts 91, 121, and 135 would have state-of-the-art equipment to aid in the prevention of CFIT accidents. The FAA's proposal also applies to operators conducting flights under Part 125 and operators of U.S.-registered airplanes under Part 129.

The FAA proposed that, for operations conducted under Part 121, the rule would apply to all turbine-powered airplanes and that, for operations under Parts 91, 125, 129, and 135, the rule would apply to all turbine-powered airplanes type certificated to have six or more passenger seats, excluding any pilot seat. (The FAA stated in the NPRM that the proposed rule applied only to turbine-powered airplanes, but the FAA indicated that it would consider comments on whether the installation of a TAWS on reciprocating engine-powered airplanes should be required. The FAA also stated that it would study data and information submitted by respondents before making a determination whether TAWS should be required for reciprocating engine-powered airplanes.)

The FAA proposed that, beginning 1 year after the effective date of the final rule, U.S.-registered turbine-powered airplanes manufactured after that date be equipped with TAWS and that existing turbine-powered airplanes be equipped with TAWS within 4 years after the effective date of the final rule. The FAA also proposed to amend 14 CFR Sections 121.360 and 135.153 to add an expiration date of 4 years after the effective date of the final rule for the use of current GPWS systems; thereafter, compliance with those sections would not be allowed instead of the provisions proposed within the NPRM. In addition, the FAA's proposal would also require operators to include in their airplane flight manuals the appropriate procedures for operating and responding to the audio and visual warnings of the TAWS.

In a December 24, 1998, letter to the FAA, the Safety Board indicated that the NPRM, if promulgated, would have a positive effect on aviation safety by reducing the possibility for CFIT accidents. However, on May 12, 1999, the Safety Board concluded that the 4-year installation time frame proposed by the FAA should be shortened to 3 years for airplanes that currently lack any GPWS protection (see section 1.18.2.4).

The FAA indicated that it expected to issue the final rule by March 2000, with an effective date 1 year after the date of issuance. According to the FAA, the final rule would mandate the installation and use of TAWS within 1 year after the effective date on new-production airplanes and within 4 years after the effective date for existing airplanes.

1.18.2.3 Department of Transportation Studies on Traditional and Enhanced Ground Proximity Warning Systems

In 1995, the FAA commissioned the DOT's Volpe National Transportation Systems Center to examine the effectiveness of GPWS and enhanced GPWS in preventing CFIT accidents in 14 CFR Part 91 operations. The center studied 44 CFIT accidents that occurred between 1985 and 1994 and involved airplanes operating under 14 CFR Part 91 with 6 to 10 passenger seats. Of the 44 airplanes, 11 were turbojets and 33 were turboprops, and none of the airplanes had GPWS installed.[137] The center used computer modeling techniques to conclude that (1) GPWS could have prevented 33 of the 44 accidents (75 percent) and 96 fatalities and (2) enhanced GPWS could have prevented 42 of the 44 accidents (95 percent) and 126 fatalities.[138]

Later in 1996, the FAA commissioned the DOT's Volpe National Transportation Systems Center for a second study that examined the effectiveness of GPWS and enhanced GPWS in preventing CFIT accidents involving airplanes operating under 14 CFR Part 121 and 135 or their foreign equivalents. The center studied 47 domestic and 104 foreign CFIT accidents that occurred between 1985 and 1995; 38 of the domestic accidents and 96 of the foreign accidents involved fatalities. The center developed a methodology and scheme for selecting a representative sample, and nine accidents were selected for detailed study and analysis.

The Volpe center found that four of the nine accidents (44 percent) should have been prevented by the basic GPWS equipment that had been installed. In two of these four accidents, the GPWS equipment either was disconnected or malfunctioned; in the other two accidents, poor flight crew coordination after the GPWS warning led to inaction rather than decisive recovery maneuvers.

The Volpe center further found that, for all nine accidents, enhanced GPWS would have provided more warning time than GPWS (which was assumed to be 12 to 15 seconds). For seven of the accidents, warning times with enhanced GPWS would have exceeded those of GPWS by more than 20 seconds; two of the accidents would have involved differences of more than 1 minute. The center concluded that "in general, [enhanced GPWS] should have provided an additional margin in which flight crews could assess their situation, discover errors, regain situational awareness, and take appropriate action before impact." The center noted only one accident for which an assumed enhanced GPWS warning duration would have been only slightly above the 12- to 15-second GPWS warning. The center argued that this case, which involved a pilot's fatal wrong turn toward mountains, might have been prevented by the visual forward-looking terrain display installed in enhanced GPWS. Thus, the center believed that it was reasonable to assume that enhanced GPWS could have prevented all nine (100 percent) of these accidents.

The Part 121 and 135 study credited GPWS as a significant factor in reducing the frequency of CFIT accidents since 1975. However, the center concluded that "there is compelling evidence of the potential effectiveness of [enhanced GPWS] in preventing CFIT accidents." The study emphasized that CFIT accident prevention would result not only from the increased warning time after the enhanced GPWS detected terrain threats but also from the system's continuous terrain display, which would enable flight crews to perceive terrain threats and respond to them well before enhanced GPWS would generate its warnings.[139]

1.18.2.4 Previous Safety Board Recommendations on Traditional and Enhanced Ground Proximity Warning Systems

In 1971, the Safety Board began issuing numerous recommendations to the FAA regarding the installation and upgrade modification of GPWS. (The FAA first mandated the installation of GPWS in 1974 for all 14 CFR Part 121 carriers.) More recently, the Safety Board has issued recommendations addressing the additional benefits of installing enhanced GPWS.

GPWS Development (A-71-53, A-72-19, and A-72-35)

On February 17, 1971, a Southern Airways Douglas DC-9-15, N92S, struck an electric transmission line static cable during a VOR approach to runway 31 at the Municipal Airport in Gulfport, Mississippi.[140] A successful missed approach was accomplished, and the aircraft landed safely. On the basis of the results of its investigation, the Safety Board issued Safety Recommendation A-71-53, asking the FAA to

> Develop a ground proximity warning system for use in the approach and landing phases of operation, which will warn flight crews of excessive rates of descent, unwanted/inadvertent descent below minimum descent altitudes, or descent through decision heights. It would be desirable if the equipment now installed could meet this need.

The FAA responded that it believed that "the present instrumentation and procedures are safe and adequate provided cockpit disciplines are maintained." The Safety Board subsequently classified this recommendation "Closed — No Longer Applicable" because it was superceded by Safety Recommendation A-72-19. That recommendation was issued as a result of the June 22, 1971, accident involving a Northeast Airlines McDonnell Douglas DC-9-31, N982NE, which struck the water during a nonprecision instrument approach to runway 24 at the airport at Martha's Vineyard, Massachusetts.[141] The Safety Board issued Safety Recommendation A-72-19, asking that

> The Administrator require all air carrier aircraft to be equipped with a functional ground proximity warning device, in addition to barometric altimeters.

On November 14, 1972, Southern Airways charter flight 932, a DC-9, N97S, crashed during a nonprecision instrument landing approach to runway 11 at the Tri-State Airport, Huntington, West Virginia.[142] The airplane impacted trees on a hill approximately 1 mile west of the runway threshold. All 71 passengers and 4 crewmembers were killed, and the airplane was destroyed. As a result of its investigation, the Safety Board issued Safety Recommendation A-72-35 to the FAA, asking that

> The Administrator evaluate the need for the installation and use of ground proximity warning devices on air carrier aircraft.

In its November 2, 1973, letter to the FAA, the Safety Board classified Safety Recommendation A-72-19 "Closed — Acceptable Alternate Action." Also, the Board classified Safety Recommendation A-72-35 "Closed — No Longer Applicable" in the same letter.

GPWS Installation for 14 CFR Part 135 Operations (A-86-109)

On August 25, 1985, Bar Harbor Airlines flight 1808, a Beech B99, N300WP, crashed during an ILS approach to Auburn-Lewiston Airport, Auburn, Maine. The airplane struck trees at an elevation of 345 feet msl in a wings-level attitude 4,000 feet from the end of the runway threshold and 440 feet to the right of the extended runway centerline. All eight airplane occupants were killed.

On September 23, 1985, Henson Airlines flight 1517, a Beech B99, N339HA, crashed during an ILS approach to Shenandoah Valley Airport, Weyers Cave, Virginia. The airplane struck trees at an elevation of 2,400 feet msl in a wings-level attitude about 6 miles east of the airport. All 14 airplane occupants were killed.

On March 13, 1986, Simmons Airlines flight 1746, an Embraer EMB-110P1, N1356P, crashed during an ILS approach to Phelps Collins Airport, Alpena, Michigan. The airplane struck trees at an elevation of 725 feet msl in a wings-level attitude about 1 1/2 miles from the end of the runway threshold and about 300 feet to the left of the extended runway centerline. Three of the nine airplane occupants were killed, five occupants received serious injuries, and one occupant received minor injuries.

The Safety Board's investigation of these accidents revealed that the accidents occurred while the airplanes were in controlled flight and the flight crews were attempting to complete precision instrument approaches in IMC.[143] None of the flight crews indicated that they were experiencing airplane or equipment problems, and none of the postaccident examinations disclosed airplane or equipment problems that would explain the accidents. As a result of these three accidents, the Safety Board issued Safety Recommendation A-86-109, which asked the FAA to

> Amend 14 CFR Section 135.153 to require after a specified date the installation and use of ground proximity warning devices in all multiengine, turbine-powered fixed-wing airplanes, certificated to carry 10 or more passengers.

On January 8, 1987, the FAA stated that it initiated a proposed regulatory project for the development of an NPRM for a GPWS requirement for 14 CFR Part 135 operators. According to the FAA, the rationale and requirements for the NPRM were finalized and would be presented to the Regulatory Review Board in early 1987. On May 15, 1987, the Safety Board asked for an update on the status of the NPRM.

On May 16, 1989, the FAA stated that the March 1989 Volpe National Transportation System Center report, titled *Investigation of Controlled Flight Into Terrain* (DOT-TSC-FA994-89-10), presented an investigation of CFIT accidents involving multiengine, fixed-wing, turbine-powered aircraft operating in accordance with 14 CFR Part 135 at the time of the accident and the potential application for a GPWS. The FAA stated that, as a result of the Volpe report and the availability of a GPWS at a more reasonable cost to commuter aircraft, the FAA was considering the issuance of an NPRM to address the intent of Safety Recommendation A-86-109. On June 20, 1989, the Safety Board stated that it was pleased that the FAA was considering the issuance of an NPRM.

On April 24, 1992, the FAA stated that, on March 17, 1992, it issued a final rule (Docket No. 26202; Amendment No. 135-42) to require that all turbine-powered (rather than only turbojet) airplanes with 10 or more seats be equipped with an approved GPWS. On June 10, 1992, the Safety Board stated that it was pleased to note that the FAA had issued the final rule and that, as a result, Safety Recommendation A-86-109 was classified “Closed — Acceptable Action.”

GPWS Installation for 14 CFR Part 91 Operations (A-92-55 and A-95-35)

On December 11, 1991, a Bruno’s, Inc., Beechjet 400, N25BR, operating under 14 CFR Part 91, impacted mountainous terrain approximately 3 minutes after takeoff from Richard B. Russell Airport near Rome, Georgia. The two flight crewmembers and all seven passengers were killed. The airplane was not equipped with a GPWS and was not required by the FARs to be so equipped. The Safety Board concluded that, if a GPWS had been installed on the airplane, a warning would have sounded about 12 seconds before impact and would have most likely provided sufficient time for the pilots to take action to avoid flying into terrain.[144] As a result of the accident, the Board issued Safety Recommendation A-92-55, which asked the FAA to

> Require all turbojet-powered airplanes that have six or more passenger seats to be equipped with a ground proximity warning system.

The FAA, however, did not agree with this recommendation. In an October 13, 1992, letter to the Safety Board, the FAA stated that, in making the determination not to require a GPWS on all turbojet-powered airplanes with six or more passenger seats, it considered, “among other factors, the operating environment most prevalent for turbojet-powered airplanes, the extent of radar service in the air traffic control system, and the employment of the minimum safe altitude warning system.” On January 6, 1993, the Board classified Safety Recommendation A-92-55 “Closed — Unacceptable Action.”

After the June 18, 1994, TAESA Learjet accident at Dulles International Airport,[145] the Safety Board issued Safety Recommendation A-95-35, which asked the FAA to Require within 2 years that all turbojet-powered airplanes with six or more passenger seats have an operating ground proximity warning system installed.

On June 14, 1995, the FAA stated that it had asked the Volpe National Transportation Systems Center to study CFIT accidents involving turbojet-powered airplanes equipped with six or more passenger seats and document those CFIT accidents that would have been avoided if GPWS or enhanced GPWS had been installed.[146] The FAA stated that it would review the results of the study to determine any regulatory action that would need to be initiated. On August 29, 1995, the Safety Board stated that it would wait for the study to be completed and then evaluate the actions taken by the FAA in response to the study’s findings.

On April 17, 1997, the FAA stated that it had initiated rulemaking proposing to mandate the installation of enhanced GPWS on all turbine-powered airplanes with six or more passenger seats.[147] The FAA also indicated that the White House Commission on Aviation Safety and Security issued a recommendation that urged the installation of enhanced GPWS on commercial aircraft. The FAA stated that it was proposing to revise 14 CFR Parts 91, 121, and 135 to address the Board’s and White House’s recommendations.

On July 31, 1997, the Safety Board said that it reviewed the results of the study by the Volpe National Transportation Systems Center. The Board stated that it was pleased that the FAA had initiated rulemaking activity to revise 14 CFR Parts 91, 121, and 135 to mandate enhanced GPWS on all turbine-powered airplanes with six or more passenger seats. The Board indicated that nearly 1 year had passed since the study was completed, and the Board hoped that the FAA’s important rulemaking action would not be further delayed.

On January 13, 1998, the Houston Gates Learjet accident occurred. This accident, which was briefly discussed in section 1.18.1.2, involved a positioning flight operating under 14 CFR Part 91. The airplane departed from Hobby Airport in Houston for George Bush Intercontinental Airport, where five people were waiting to board the airplane for a 14 CFR Part 135 charter flight to Fargo, North Dakota. The captain and first officer — the sole occupants aboard the flight — were killed when the airplane struck trees and impacted the ground, and the airplane was destroyed by impact forces and fire. The airplane was not equipped with a GPWS and was not required by the FARs to be so equipped. Although the Safety Board determined that the probable cause of this accident was flight crew error, the Board also found that the lack of an FAA requirement for a GPWS on the airplane was a factor in the accident.

On May 12, 1999, the Safety Board stated that the circumstances of the Houston Learjet accident, the TAESA Learjet accident, and the Bruno’s Beechjet accident clearly indicated the potential to reduce CFIT accidents by requiring the installation of a GPWS in turbojet-powered airplanes equipped with six or more passenger seats. The Board further stated that the 1996 DOT study provided compelling evidence that Safety Recommendation A-95-35 should be broadened to include turboprop-powered airplanes and require the installation of enhanced GPWS. As a result, the Safety Board classified Safety Recommendation A-95-35 “Closed — Acceptable Action/Superseded.”[148]

Enhanced GPWS for Transport-Category Airplanes (A-96-101)

On December 20, 1995, American Airlines flight 965, a Boeing 757, N651AA, was on a regularly scheduled 14 CFR Part 121 flight from Miami, Florida, to Cali, Colombia, when it struck trees and crashed into the side of a mountain in night VMC.[149] Of the 8 crewmembers and 156 passengers aboard the airplane, all but 4 were killed. The airplane was equipped with a GPWS, as required. Approximately 12 seconds before impact, the GPWS began issuing aural warnings of “TERRAIN” and “PULL UP.”

However, the GPWS did not provide the warning in time for the flight crew to successfully avoid crashing into the mountainous terrain. As a result of this accident, the Safety Board issued Safety Recommendation A-96-101, asking the FAA to

> 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.

On December 31, 1996, the FAA stated that it had begun evaluating the effectiveness of enhanced GPWS. Further, the FAA stated its belief that enhanced GPWS would perform as intended and should significantly increase a pilot's situational awareness. The FAA indicated that evaluations to date revealed that enhanced GPWS would be a valuable aid in preventing CFIT accidents. The FAA anticipated completing its evaluation by March 1997 and stated that it would initiate appropriate action based on the results of the evaluation.

On April 11, 1997, the Safety Board acknowledged that the FAA was considering the issuance of an NPRM to require enhanced GPWS equipment on all civil, turbine-powered aircraft with six or more passenger seats. The Board indicated that it would wait to review the FAA's final action.

On May 4, 1999, the FAA stated that, in August 1998, it issued an NPRM proposing to require the installation and use of TAWS on any U.S.-registered turbine-powered airplane with six or more passenger seats operating under 14 CFR Parts 91, 121, and 135. According to the FAA, because operators under 14 CFR Part 125 and operators of U.S.-registered airplanes under 14 CFR Part 129 must comply with 14 CFR Part 91, they would also have to meet the proposed requirements of the NPRM. The FAA further indicated that it had issued TSO C151, "Terrain Awareness and Warning System," for public comment. According to the FAA, TSO C151 would prescribe the minimum operational performance standards that a TAWS must meet.[150] The FAA stated that the comment period for TSO C151 was from November 4, 1998, to January 26, 1999. The FAA also stated that it had extended the ending date of the comment period for the NPRM from November 24, 1998, to January 26, 1999, to coincide with the ending date of the comment period for the TSO.

On July 13, 1999, the Safety Board stated that, pending the issuance of the final rule on the installation and use of TAWS and TSO C151, Safety Recommendation A-96-101 was classified "Open — Acceptable Response." In an October 1, 1999, response, the FAA stated that it had issued the final TSO on August 16, 1999. The FAA also stated that it expected to issue the final rule by March 2000 with an effective date of 1 year after the date of issuance.

The Safety Board's evaluation and classification of Safety Recommendation A-96-101 are discussed in section 2.8.2.

Enhanced GPWS for Turbine-Powered Airplanes (A-99-36)

As part of its investigation into the 1998 Houston Learjet accident (see the discussion regarding Safety Recommendation A-95-35), the Safety Board concluded that the 4-year TAWS installation time frame should be shortened for airplanes that lack any GPWS protection. On May 12, 1999, the Safety Board issued Safety Recommendation A-99-36, which asked the FAA to

> Require, within 3 years, that all turbine-powered airplanes with six or more passenger seats that are not currently required to be equipped with a ground proximity warning system (GPWS) have an operating enhanced GPWS (or terrain awareness and warning system).

On July 26, 1999, the FAA stated that, in August 1998, it had issued an NPRM on the installation and use of TAWS on any U.S.-registered turbine-powered airplane with six or more passenger seats operating under 14 CFR Parts 91, 121, and 135. The FAA indicated that the NPRM proposed adding new rules that would prohibit the operation of certain airplanes unless those airplanes were equipped with a TAWS that met the minimum operational performance standards prescribed in TSO C151, "Terrain Awareness and Warning System."

The FAA also stated that, on May 27, 1999, it published a change to the proposed TSO to include two classes (A and B) of TAWS equipment. According to the FAA, TSO C151 Class A equipment would be required for airplanes operated under 14 CFR Part 121 and for airplanes configured with 10 or more passenger seats operating under 14 CFR 150 See the discussion in Safety Recommendation A-99-36 for detailed information on TSO C151 Part 135, and TSO C151 Class B equipment would be the minimum requirement for airplanes operating under 14 CFR Part 91 and for airplanes configured with six to nine passenger seats operating under 14 CFR Part 135. The FAA indicated that both classes of equipment would include the TAWS features of comparing airplane position information with an on-board terrain database and providing appropriate caution and warning alerts, if necessary. Further, the FAA stated that it revised the proposed TSO to include the airworthiness requirements for both classes of equipment.

The FAA indicated that it expected to issue the final TSO by September 1999 and the final rule by March 2000, with an effective date 1 year after the date of issuance. According to the FAA, the final rule would mandate the installation of TAWS within 1 year after the effective date on new-production airplanes and within 4 years after the effective date for existing airplanes. The FAA indicated that these compliance dates, which were established in the current NPRM, were developed based on product availability and the anticipated manufacturing approval process. The FAA further indicated that a change in the compliance dates, as recommended in this safety recommendation, would require publishing a supplemental NPRM. The FAA believed that any change to the current rulemaking effort would delay the implementation of TAWS well beyond the proposed dates of the current final rule, as well as the compliance dates included in the recommendation. On October 1, 1999, the FAA stated that it had issued the TSO C151 on August 16, 1999.

The Safety Board's evaluation and classification of Safety Recommendation A-99-36 are discussed in section 2.8.2.

1.18.3 Controlled Flight Into Terrain Accident Information

1.18.3.1 Flight Safety Foundation Study of Controlled Flight Into Terrain Accidents

In the early 1990s, the Flight Safety Foundation (FSF) created a CFIT Awareness Task Force to promote general CFIT awareness. This task force evolved into an international Approach and Landing Accident Reduction Task Force, working under the auspices of the FSF. According to statistics compiled by the task force, CFIT accidents have killed more than 9,000 passengers and crewmembers since the beginning of commercial jet operations in the late 1950s. The statistics also indicate that, between 1988 and 1997, more than 2,800 people were killed in 39 CFIT-related accidents worldwide.

The FSF task force estimated that about 25 CFIT accidents occur worldwide each year involving large commercial jet transports and large commuter and regional turboprop airplanes. Several factors that frequently appeared in CFIT accident reports included night and limited visibility conditions, terrain not observed until just before impact, loss of horizontal or vertical situational awareness, unfamiliarity with terrain and obstructions, flight crew uncertainty about altitudes and distance from the airport, navigational equipment improperly set or misinterpreted by the flight crew, and an unstabilized approach.

The FSF, using statistics from the United Kingdom's CAA global database, found that 287, or 46 percent, of the 621 fatal CFIT accidents worldwide between 1980 and [* 1996] occurred during the approach and landing phase of flight. A study commissioned by the CAA for the FSF[151] examined these 287 fatal approach and landing accidents.[152] According to the study, these 287 accidents resulted in 7,185 fatalities to passengers and crewmembers, which averaged 25 fatalities per accident, or 63 percent of the total aircraft occupants.

The study indicated that 75 percent of the accidents occurred when a precision approach aid was [* not] available [* or not] used and that nighttime accidents occurred at three times the rate of those that occurred during daylight conditions. The lack of ground aids was cited in at least 25 percent of the accidents. The study concluded that the "most frequent circumstantial factors were non-installation of currently available safety equipment (generally GPWS systems) and the failure to emphasize the use of crew resource management."

The study determined that, in 279 of the accidents,[153] the 5 most frequently identified primary causal factors — omission of action/inappropriate action, lack of positional awareness in the air, flight handling, "press-on-itis," and poor professional judgment/airmanship — accounted for 71 percent of the accidents.[154] According to the FSF, omission of action/ inappropriate action generally referred to the crew continuing the descent below the DH or MDA without visual reference or when visual cues were lost. Lack of positional awareness in the air generally involved a lack of appreciation of the aircraft's proximity to high ground, frequently when the aircraft was not equipped with a GPWS and when precision approach aids were not available. Press-on-itis referred to a flight crew's "determination to get to a destination or persistence in a situation when that action is unwise." The study also determined that all five primary causal factors involved crewmembers.[155]

The study reported that the number of accidents and the number of fatalities showed an overall increasing trend and that, if the trend were to continue, " … by 2010 there will be 23 fatal ALAs [approach and landing accidents] with a total of 495 fatalities annually involving Western-built aircraft (commercial jets, business jets and turboprop airplanes) … ." On the basis of the results of this study, the FSF Approach and Landing Accident Reduction Task Force issued nine [* preliminary] conclusions and recommended several initiatives to support each conclusion.[156] (The recommendations for each [* preliminary] conclusion are detailed in appendix C.) The [* preliminary] conclusions were as follows:

- Establishing and adhering to adequate standard operating procedures and CRM processes will improve approach and landing safety.
- Improving communication and mutual understanding between ATC services and flight crews of each other's operational environment will improve approach and landing safety.
- Unstabilized and rushed approaches contribute to ALAs.
- Failure to recognize the need for and to execute a missed approach, when appropriate, is a major cause of ALAs.
- The risk of ALAs is higher in operations conducted during low light and poor visibility, on wet or otherwise contaminated runways, and with the presence of optical physiological illusions.
- Using the radio altimeter as an effective tool will help prevent ALAs.

- When the PIC [pilot-in-command] is the PF and the operational environment is complex, the task profile and workload reduce PF flight management efficiency and decision-making capability in approach and landing operations.

- Collection and analysis of in-flight parameters (for example, flight operations quality assurance programs) can identify performance trends that can be used to improve the quality of approach and landing operations.

- Global sharing of aviation information decreases the risk of ALAs.

1.18.3.2 Factors Involved in Recent Controlled Flight Into Terrain Accidents and Incidents

A British Airways Boeing 777 captain who was a member of the FSF's Approach and Landing Accident Reduction Task Force and CFIT Awareness Task Force testified at the Safety Board's public hearing about the factors that have been involved in CFIT accidents and incidents. The captain testified that five of six CFIT accidents in 1996 and 1997 occurred during nonprecision approaches. The captain also said that, from 1988 to 1997, one-half of the commercial jet CFIT accidents were during step-down approaches, even though most of those airplanes had DME available.[157]

The captain testified that, according to the accident data, the chances of a CFIT accident occurring during a nonprecision approach is five times greater than during a precision approach. The captain also stated that nonprecision approaches are generally much more complex than precision approaches because, for many pilots, nonprecision approaches are less familiar, are more prone to error, and require more comprehensive briefing. Further, the captain stated that nonprecision approaches need particularly careful and accurate monitoring and that it is possible, with complex step-down procedures, for steps to be missed or taken out of order. The captain added, "in other words, to get one step ahead of the airplane could be fatal." He recommended eliminating step-down nonprecision approaches " … because the accident data says we should … ." In addition, the captain testified that nonprecision approaches need much more carefully managed airplane crew and checklist management because many CFIT accidents occur when the crew is preoccupied or distracted by other tasks.

The captain stated that 70 percent of the CFIT accidents occurred on final approach and that most of these aircraft were " … in line with the runway." The captain also stated that " … many accident aircraft [were] underneath the three-degree glideslope [of a precision approach]." Figure 10 shows vertical profile information that was available from the 40 CFIT accidents and incidents that occurred between 1986 and 1990, as prepared by Boeing and provided by the FSF's CFIT Awareness Task Force.

The captain stated his belief that no single measure or piece of aircraft equipment can prevent CFIT accidents and that a range of measures suited to a particular operator and operating environment is needed. The captain added that ICAO has planned a series of CFIT-related actions, including the following:

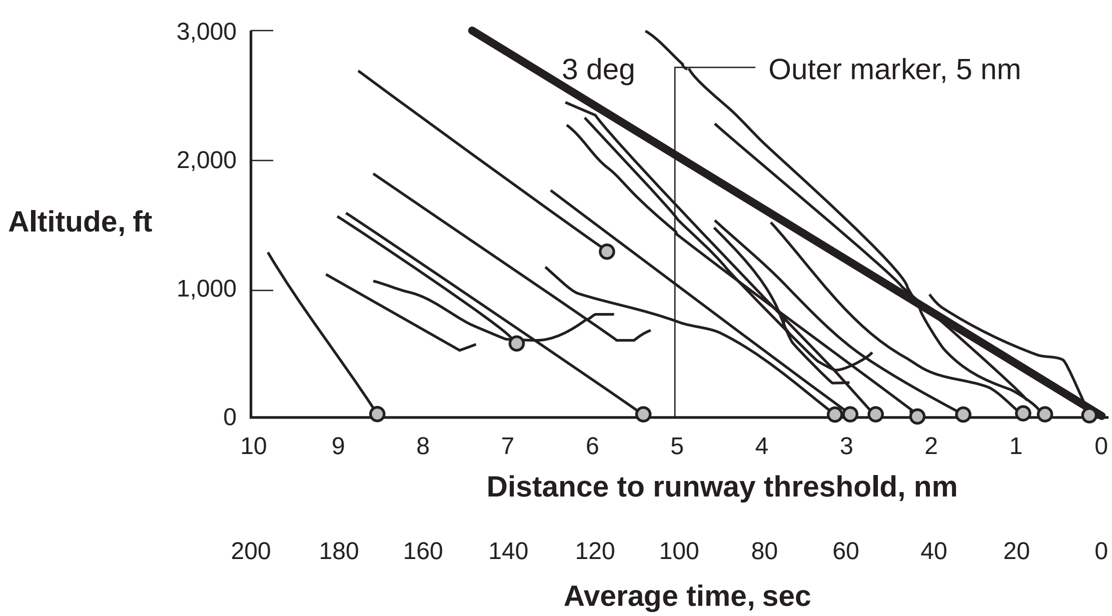

Figure 10. Vertical profile information from the 40 CFIT accidents and incidents between 1986 and 1990.

Reproduction courtesy of The Boeing Company and the Flight Safety Foundation's Controlled Flight Into Terrain Awareness Task Force.

- the adoption of colored terrain and minimum safe altitude contour presentation on approach procedure charts to improve their readability and understanding by a flight crew, particularly in the cockpit environment at night;

- new requirements and new emphasis on standard operating procedures (specifically, altitude awareness procedures), including the use of standard or automated callouts, guidance on the use of autopilot, and the incorporation of stabilized approach procedures concepts;

- changes to instrument approach procedure design, including the optimum angle for nonprecision approaches and the application of vertical navigation (VNAV) or FMS during nonprecision approaches; and

- the translation of the FSF's Education and Training Aid (see section 1.18.3.3) from English into the other five languages used by ICAO.[158]

1.18.3.3 Controlled Flight Into Terrain Training Aids

The Boeing Commercial Airplanes Group, along with the FAA, and the FSF have developed and published CFIT educational materials and training aids for use by operators. The purpose of each aid is to heighten flight crew awareness to CFIT precursors and the methods and techniques to avoid this type of accident.

The Boeing/FAA CFIT Education and Training Aid, which became available to air carriers in 1997, is presented in five sections. According to the FAA, this training aid, along with a new videotape, was distributed to all 14 CFR Part 121 and 135 operators for inclusion in their training programs. Section one provides a broad overview for airline executives of CFIT problems and possible solutions. Section two, titled "A Decision Maker's Guide," describes airline operations, aviation industry regulators, and industry efforts to eliminate CFIT. Section three, titled "An Operator's Guide," describes causal factors of CFIT accidents, the traps in which flight crews can find themselves, and specific in-flight escape maneuvers. Section four describes a model CFIT airline education program. Section five provides additional background information on CFIT and references selected reading materials and accident and incident information.

The FSF's CFIT task force developed a CFIT checklist in 1993 to aid in the avoidance of CFIT accidents. The checklist was designed so that the user, before a flight, could evaluate the risk factors and identify the potential for a CFIT accident. For example, the checklist indicated that flying in night IMC significantly increases the risk of a CFIT accident occurring. The checklist is divided into two diagnostic parts. The first part, titled "CFIT Risk Assessment," includes negative destination CFIT risk factors, such as VOR/DME approaches, airports near mountainous terrain, and radar coverage limited by terrain masking. Further, this assessment evaluates risk multipliers, such as IMC weather and extended crew duty days. The second part, titled "CFIT Risk Reduction Factors," includes positive company management traits and the availability of CFIT training programs.

1.18.3.4 Previous Safety Board Recommendations Related to Controlled Flight Into Terrain

Since the early 1970s, the Safety Board has issued numerous safety recommendations to the FAA in response to CFIT accidents, including those discussed as part of the GPWS and enhanced GPWS recommendations in section 1.18.2.4 and approach procedure design recommendations in section 1.18.4.4. This section provides information on other CFIT-related safety recommendations.

On December 20, 1995, the American Airlines flight 965 accident near Cali, Colombia, occurred.[159] On October 16, 1996, the Safety Board issued Safety Recommendations A-96-93 through -95, A-96-102, and A-96-106 as a result of the findings from this accident investigation.[160]

Safety Recommendation A-96-93 asked the FAA to

> 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.

On April 23, 1997, the FAA stated it agreed with the intent of Safety Recommendation A-96-93 and that it had completed its efforts to evaluate terrain avoidance procedures. The FAA stated that, in January 1997, it developed and published the CFIT Education and Training Aid along with Boeing (see section 1.18.3.3). The FAA also stated that, on February 25, 1997, it issued a revision (Change 2) to AC-120-51B, "Crew Resource Management," Appendix 3, "Appropriate CRM Training Topics," paragraph 2(1), to recommend that CRM training in LOFT or Special Purpose Operational Training for flight crewmembers contain a CFIT scenario. According to the FAA, this paragraph recommends that the training should emphasize prevention through effective communication and decision behavior and the importance of immediate, decisive, and correct response to a ground proximity warning.

On November 13, 1997, the Safety Board acknowledged the progress made by the FAA but noted that the FAA's response did not address whether the escape/terrain avoidance procedures would be included in the procedural sections of approved operations manuals. Pending further information from the FAA, Safety Recommendation A-96-93 was classified "Open — Acceptable Response."

On August 11, 1999, the FAA stated that it would issue a flight standards information bulletin that directed POIs to ensure that the aircraft-specific procedure for maximum escape performance (as depicted in the CFIT training aid), or an equivalent of that procedure, was contained in each appropriate FAA-approved operations manual. The FAA indicated that it planned to issue the bulletin by the end of August 1999.

On October 20, 1999, the FAA indicated that it had issued Flight Standards Information Bulletin for Air Transportation 99-08, "Controlled Flight Into Terrain (CFIT) Training," on October 5, 1999. According to the FAA, the bulletin announces the publication of the CFIT Education and Training Aid and informs POIs that the training aid is posted on the FAA's Web site. The FAA stated that the bulletin also directs POIs to ensure that the aircraft-specific procedure for maximum escape performance is contained in each appropriate FAA-approved operations manual.

Safety Recommendation A-96-94 asked the FAA to

> 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 this information to obtain maximum possible airplane climb performance.[161]

On December 31, 1996, the FAA stated that it had begun an evaluation to assess the operational requirements for an angle-of-attack[162] indicator. The FAA indicated that the evaluation should be completed by March 1997.

On April 11, 1997, the Safety Board stated its understanding that the FAA's assessment would include implementation and training requirements, the complexity and cost of the system, and other functions and would indicate the angle-of-attack for maximum rate climb. The Safety Board also stated its understanding that, if angle-of-attack indicators were warranted, the FAA would take appropriate regulatory action. Pending an evaluation of the FAA's completed action, Safety Recommendation A-96-94 was classified "Open — Acceptable Response."

On May 4, 1999, the FAA stated that it had evaluated the requirements for the display of angle-of-attack information to obtain the maximum airplane climb performance. The FAA indicated that angle-of-attack information during an escape maneuver could provide some improvement in climb performance but that the prevention of terrain escape maneuvers would provide a much greater safety benefit than the climb performance improvements gained by the display of angle-of-attack information.

The FAA indicated that it had reviewed CFIT accidents and analyses of CFIT accident data prepared by various organizations. The FAA stated that its review found that accidents have only rarely been caused by the failure to obtain the maximum possible airplane climb performance during the ground proximity escape maneuver. Thus, the FAA believed that more effective prevention of CFIT accidents would yield the greatest safety benefit.

The FAA cited initiatives to prevent CFIT accidents, including TAWS and the use of FMS with VNAV capability for constant angle of descent approaches. The FAA believed that these initiatives would greatly improve pilots' situational awareness with regard to terrain and would directly reduce the likelihood that pilots using these systems would need to perform a ground proximity escape maneuver. Further, the FAA believed that the safety gains from improvements in escape maneuver climb performance, gained by the introduction of angle-of-attack information, would be overshadowed by the safety gains from the implementation of TAWS, especially when that system is combined with other technologies, such as FMS with VNAV capability and GPS.

Regarding the training portion of Safety Recommendation A-96-94, the FAA stated that it was revising air carrier pilot training requirements contained in 14 CFR Part 121 to include mandatory training in the ground proximity escape maneuver recommended by manufacturers for their specific airplane(s). The FAA indicated that one objective of this training would be to improve pilot actions in achieving maximum airplane climb performance during the escape maneuver. In addition, the FAA stated that the regulatory proposal would refer to the guidance in the CFIT Education and Training Aid, which provides instructions on how to achieve the optimum angle-of-attack (given the indications available in the airplane) and the manufacturers' recommended ground proximity escape maneuvers.

Safety Recommendation A-96-95 asked the FAA to

> 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.

On April 23, 1997, the FAA stated it agreed with the intent of Safety Recommendation A-96-95 and that it had completed its efforts to evaluate terrain avoidance procedures. The FAA stated that, in January 1997, it developed and published the CFIT Education and Training Aid along with Boeing. The FAA also stated that, on February 25, 1997, it issued Change 2 to AC-120-51B Appendix 3, paragraph 2(1), to recommend that CRM training in LOFT or Special Purpose Operational Training for flight crewmembers contain a CFIT scenario. According to the FAA, this paragraph recommends that the training should emphasize prevention through effective communication and decision behavior and the importance of immediate, decisive, and correct response to a ground proximity warning.

On November 13, 1997, the Safety Board acknowledged the progress made by the FAA but noted that the FAA's response did not indicate that the newly developed CFIT training program was mandatory, as urged by the recommendation. Pending further information from the FAA, Safety Recommendation A-96-95 was classified "Open — Acceptable Response."

On August 11, 1999, the FAA stated that it had initiated an NPRM proposing to mandate training in CFIT, including flight training in simulators and the ground proximity escape maneuver. The FAA indicated that the NPRM was expected to be published in December 2000.

The Safety Board's evaluation and classification of Safety Recommendation A-96-95 are discussed in section 2.8.

Safety Recommendation A-96-102 asked the FAA to

> Require that all approach and navigation charts graphically present terrain information.[163]

On December 31, 1996, the FAA stated that it agreed with the intent of this recommendation. However, the FAA stated that it was not necessary to depict terrain on IFR en route low-altitude charts because the off-route obstruction clearance altitudes adequately presented terrain and obstruction clearance information. In addition, the FAA indicated that the Government/Industry Charting Forum, chaired by the FAA's Air Traffic Service, was evaluating the possibility of adding terrain information (contour lines and shading) graphically on approach charts.

On April 11, 1997, the Safety Board stated that, although the FAA's action regarding approach charts was appropriate, the Board did not agree with the FAA that current off-route obstruction clearance altitudes adequately presented terrain and obstruction clearance information. The Board reiterated that the intent of this recommendation was to have terrain information graphically presented on all approach and navigation charts.

On February 19, 1998, the FAA stated that the Task Group 31 from the Air Cartographic Committee (a Government interagency and aviation industry committee) was evaluating the possibility of adding contour lines and shading on the plan view portion of approach charts for terrain-impacted airports only. The FAA also stated its belief that the addition of contour lines and tinting to IFR en route charts has not been supported by users and industry personnel and that sufficient information on en route charts obviates the need for such changes. Further, the FAA stated that overlaying additional information into charts that already contained a considerable amount of information could diminish the clarity of existing information on those charts.

On September 3, 1998, the Safety Board stated that the points the FAA raised with regard to adding information to en route charts were valid. However, the Board noted that these concerns did not apply to terminal navigation charts and approach charts. The Safety Board continued to believe that the FAA should do all it can to enhance pilots' situational awareness regarding proximity to terrain and that adding readily interpretable terrain information to navigation charts would be an economical way to accomplish this goal.

The Safety Board indicated that it would await FAA action regarding approach charts after the efforts of Task Group 31 were completed. Because the FAA appeared unwilling to require that terminal charts graphically portray terrain information to help prevent CFIT accidents, Safety Recommendation A-96-102 was classified "Open — Unacceptable Response."

On July 7, 1999, the FAA stated that it met with the Safety Board on March 12, 1999, to clarify the intent of this safety recommendation and discuss the issue of adding terrain contours to all charts. At this meeting, the FAA indicated that it would consider placing terrain contours only on en route area charts. According to the FAA, this plan was proposed in April 1999 at the Government/Industry Aeronautical Charting Forum, which endorsed the proposal. The FAA stated that it was developing funding requirements with the National Oceanic and Atmospheric Administration and that, pending funding approval, it would submit a requirements document to the Interagency Air Cartographic Committee to amend the chart specifications to add terrain contours to en route area charts. The FAA also stated that it was planning to add terrain contours on instrument approach procedure charts for terrain-impacted airports.

On September 24, 1999, the Safety Board stated that, on the basis of the FAA's commitment to consider adding terrain contours to en route area charts only, Safety Recommendation A-96-102 was classified "Open — Acceptable Alternate Response."

Safety Recommendation A-96-106 asked the FAA to

> 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.

On December 31, 1996, the FAA stated that it would fund a research project to determine cues that flight crewmembers could readily recognize to indicate situational awareness problems. According to the FAA, this project would focus on developing specific cues for situational awareness in automated cockpits. The FAA indicated that, as soon as this project was completed, it would revise AC 120-51B to include guidance on training flight crews in cue recognition. On April 11, 1997, the Safety Board stated that it was waiting to evaluate the FAA's revised version of AC 120-51B.

On August 3, 1998, the FAA stated that the results of its research project were outlined in a report, titled *Guidelines for Situation Awareness Training*, which was published in February 1998. According to the FAA, the report included an overview, specific training tips, and sample training courses for use by the aviation community. The FAA indicated that it would incorporate guidance on cue recognition training for flight crewmembers in AC 120-51B. On November 2, 1998, the Safety Board restated that it would wait to evaluate the FAA's revised version of AC 120-51B.

On December 11, 1998, the FAA stated that, on October 30, 1998, it issued AC 120-51C, "Crew Resource Management Training," a revision to AC 120-51B. The FAA stated that Appendix 3, "Appropriate CRM Training Topics," paragraph 2(m), specifically addressed training for pilots in recognizing cues that indicate lack or loss of situational awareness in themselves and others and training in countermeasures to restore that awareness. According to the FAA, paragraph 2(m) reiterates that training should emphasize the importance of recognizing each pilot's relative experience level, experience in specific duty positions, preparation level, planning level, normal communication style and level, overload state, and fatigue state. Further, the FAA stated that training should emphasize that improper procedures, adverse weather, and abnormal or malfunctioning equipment might reduce situation awareness. In addition, the FAA stated that AC 120-51B references the *Guidelines for Situation Awareness Training* report because of the AC's expanded guidance on cues and countermeasures.

On March 1, 1999, the Safety Board stated that the amendments to AC 120-51B, which resulted in the issuance of AC 120-51C, met the intent of this recommendation. Accordingly, Safety Recommendation A-96-106 was classified "Closed — Acceptable Action."

1.18.3.5 Previous Controlled Flight Into Terrain Accidents Related to Nonprecision Instrument Approach Procedures

As stated in section 1.18.3.2, accident data has shown that the chances of a CFIT accident occurring during a nonprecision approach is five times greater than during a precision approach. In addition to the CFIT events discussed previously (including the USAir flight 105 incident in Kansas City, Missouri, and the American Airlines flight 965 accident in Cali, Colombia) and in section 1.18.4.4 (American Airlines flight 1572 in East Granby, Connecticut), the Safety Board has investigated the following CFIT accidents that occurred while the airplane was on a nonprecision approach:

On February 18, 1989, a Flying Tigers Boeing 747-200, operating as a cargo flight under 14 CFR Part 121, crashed while on an NDB approach to Subang International Airport in Kuala Lumpur, Malaysia. Night visual conditions prevailed around the airport at the time of the accident. All four airplane occupants were killed, and the airplane was destroyed. The investigation into this accident was being conducted by the Department of Civil Aviation of the Government of Malaysia with the assistance of the Safety Board.

On June 2, 1990, about 0937 Alaskan daylight time, Markair, Inc., flight 3087, a Boeing 737-2X6C, N670MA, operating under 14 CFR Part 121, crashed about 7 1/2 miles short of runway 14 at Unalakleet, Alaska, while executing a localizer-only approach in IMC. One flight attendant received serious injuries; the captain, the first officer, and a flight attendant received minor injuries; and the aircraft was destroyed. The Safety Board determined that the probable cause of the accident was deficiencies in flight crew coordination, the crew's failure to adequately prepare for and properly execute the localizer-only runway 14 nonprecision approach, and the crew's subsequent premature descent.[164]

On April 3, 1996, a U.S. Air Force CT-43A (737-200) carrying the Secretary of Commerce, other Government officials, and a delegation of business executives crashed on a mountainside while on an NDB approach to Cilipi Airport in Croatia. All 35 people aboard the airplane were killed. The Safety Board provided technical assistance to the Air Force during its investigation.[165]

1.18.4 Industry Actions to Improve the Safety of Nonprecision Instrument Approaches Conducted by Air Carriers

1.18.4.1 Nonprecision Approach Procedures

According to the Air Line Pilots Association (ALPA),[166] limited data indicate that airline transport crews conduct only about one to three nonprecision approaches per year and practice these approaches in a simulator "just as infrequently." Thus, ALPA concluded that the risk associated with this "inherently less safe type of approach" is compounded by the infrequency of flight crew exposure and practice. ALPA stated that most nonprecision approaches are presented in a series of step-down altitudes and that, although step-down altitudes may be satisfactory for light, slow, maneuverable aircraft, they are unacceptable for transport-category aircraft. ALPA further stated that these step-down altitudes are in fact directly contrary to the underlying concept of the stabilized approach because they require multiple power and pitch changes to be flown as charted. ALPA believed that approach charts and procedures should be modified to provide the information necessary to conduct a stabilized descent without explicit vertical guidance.

The issue of nonprecision approaches flown by air carrier (primarily turbojet) airplanes has been debated, especially in light of the recent CFIT accidents that occurred during the execution of a nonprecision approach. ALPA stated that "all turbojet air carrier airports need to have a precision approach available at all times in the appropriate landing direction."

Further, ALPA believed that it is "problematic at best" for a "500,000 pound aircraft to transition from level flight (at MDA) and very high thrust settings, to a stabilized approach and touchdown in 15 to 20 seconds (the distance covered in one mile visibility at 180 knots)" because of the size of the aircraft and approach speeds at which the nonprecision approaches are flown.

1.18.4.2 Approach Chart Terrain Depiction

According to testimony at the Safety Board's public hearing by the Senior Corporate Vice President of Flight Information Technology and External Affairs for Jeppesen Sanderson, Inc., approach chart manufacturers use various methods to depict obstructions and high terrain on published approach charts. Some en route charts and the plan view of some terminal approach charts use contour lines and color shading to depict various height gradients with symbols for high obstructions. Other charts use broader colored areas for terrain depiction and specify a minimum sector altitude for obstacle clearance in segmented areas around the airport. In some instances, terrain may be depicted on the plan view of some approach charts but not on other charts published by the same manufacturer.

Currently, no chart publisher depicts terrain or obstructions on the profile view, which depicts the inbound course descent profile from the IAF to the landing or MAP. Further, the FAA Terminal Instrument Procedures (TERPS) manual contains no requirement for a standardized format that chart manufacturers must adhere to when depicting terrain on an approach chart, except for the requirement to depict the height of certain obstructions.

The Jeppesen Sanderson official testified that "the Agana ILS 6 Left approach did not have terrain [depicted on the chart] … because through the agreements that we've had with our airlines, seminars in the airline community, as well as a lot of the general aviation input, it is believed by Jeppesen that … there should be criteria because you don't want terrain to be on all charts; you want it there when it's significant." The official added that, for Jeppesen to depict terrain on a chart, there needs to be at least one elevation that is 4,000 feet or greater above the airport in at least one plan view of the airport or, if there is one elevation that is 2,000 feet above the airport within 6 miles, then contour lines need to start at the nearest 1,000 feet to the airport elevation and appear at 1,000-foot intervals all the way up to the top altitude that is depicted.

The Jeppesen official's testimony discussed the difficulties of obtaining accurate worldwide terrain data through public sources. The official said that inaccurate information was one of several reasons for not providing terrain information on the charts. The official further stated that there are many sources for terrain information but that the information needs to be publicly available so that chart manufacturers can have ready access.

The Chief Engineer of Flight Safety Systems at AlliedSignal, Inc., testified at the Safety Board public hearing about the acquisition and accuracy of terrain data. The official indicated that terrain data needs to be collected to build the database not only for chart manufacturers but also for companies that are incorporating such data into enhanced GPWS or TAWS. The official also testified that some countries still consider terrain data to be a military secret.

1.18.4.3 Federal Aviation Administration Form 8260

FAA Form 8260 provides charting companies with information for publishing instrument procedures. This form includes data for the terminal area and final and missed approach standards. The manager of the FAA's Western Flight Procedures Development Branch testified at the Safety Board's public hearing that the FAA distributes approach procedures to industry user groups (including ALPA, the Air Transport Association, and the Aircraft Owners and Pilots Association) and airport operators for comment. The manager testified that the user groups receive information that describes the approach in words or numbers and does not depict the proposed published approach. According to ALPA's submission, the information that the FAA releases "bears no resemblance to the final user product," which "seriously hampers the ability to readily and effectively critique the proposed approach procedure."

1.18.4.4 Previous Safety Board Recommendations Related to Approach Procedure Design

On November 12, 1995, American Airlines flight 1572, a McDonnell Douglas MD-83, N566AA, collided with trees in East Granby, Connecticut, while on final approach to runway 15 at Bradley International Airport in Windsor Locks, Connecticut.[167] The airplane then landed safely at the airport. Of the 78 airplane occupants, 1 passenger received minor injuries during the emergency evacuation. The Safety Board determined that the probable cause of this accident was the flight crew's failure to maintain the required MDA until the required visual references identifiable with the runway were in sight. As a result of its investigation, the Board issued Safety Recommendations A-96-128, A-96-129, and A-96-131 through -133 on November 13, 1996.

Safety Recommendation A-96-128 asked the FAA to

> Evaluate Terminal Instrument Procedures design criteria for nonprecision approaches to consider the incorporation of a constant rate or constant angle of descent to minimum descent altitude in lieu of step-down criteria.

On February 24, 1997, the FAA stated that it would begin implementation of instrument approach development proposals in late 1997. On June 26, 1997, the Safety Board stated that it was waiting to review the pending FAA proposals in response to this recommendation. On January 28, 1998, the FAA stated that it developed draft criteria to provide a constant angle of descent for aircraft with area and vertical navigation and that these criteria were incorporated into a draft order, which was being coordinated with industry. The FAA anticipated that the final order would be published in June 1998. On April 15, 1998, the Safety Board stated that it would wait to review the final order.

On August 7, 1998, the FAA stated that, on February 13, 1998, it issued a revision (Change 17) to Order 8260.3B, "United States Standard Terminal Instrument Procedures (TERPS)," which requires descent angles and descent gradients to be computed for nonprecision approaches by the FAA and subsequently depicted on aeronautical charts supplied by the National Ocean Service. The FAA indicated that the angles and descent gradients would be integrated during biennial reviews of each instrument approach procedure. According to the FAA, Change 17 states that the optimum gradient on the final approach segment is 318 feet per nautical mile, which approximates a 3° descent angle and allows VNAV-equipped aircraft to perform a stabilized descent on final approach using a computed VNAV path. Depiction of a descent gradient allows pilots to determine a target rate of descent to be maintained to fly a stabilized final approach path. Change 17 also addresses the elimination of a step-down fix through manipulation of either the FAF altitude/location or the step-down fix altitude/ location. When use of the step-down fix cannot be avoided, the descent angles are provided for the portion of the final segment from the step-down fix to the runway threshold.

Additionally, the FAA stated that, on May 26, 1998, it issued Order 8260.47, "Barometric Vertical Navigation (VNAV) Instrument Procedures Development." According to the FAA, this order contains criteria for design of stand-alone area navigation approaches using barometric VNAV guidance on the final approach segment. Approaches so designed are to specify the vertical path angle from the FAF to the runway threshold. In addition, the MDA of a conventional nonprecision approach has been replaced by a decision altitude. The FAA stated that the use of a decision altitude was authorized because an allowance has been made for height loss during a missed approach and an obstacle assessment has been conducted of the visual segment (runway threshold to decision altitude point) and found to be clear of obstructions.

Because the new standards met the intent of Safety Recommendation A-96-128, it was classified "Closed — Acceptable Action" on December 8, 1998.

Safety Recommendation A-96-129 asked the FAA to

> Examine and make more effective the coordinating efforts of the flight inspection program and the procedures development program, with emphasis on ensuring quality control during the development, amendment, and flight inspection process for instrument approaches.

On February 24, 1997, the FAA said that it had established a test program to ensure interaction between the flight inspection program and the procedures development program. On June 11, 1997, the FAA stated that it completed its first test program to ensure interaction between the flight inspection program and the procedures development program. According to the FAA, the test program involved the placement of a liaison position (effective March 16, 1997) in the flight inspection central operations office to respond to queries and ensure resolution of all issues. The FAA added that the individual in this position served as a focal point for the two offices to correct discrepancies found during flight, enhanced the interaction between the offices, conveyed information to flight inspection crews, and ensured standardization.

On September 8, 1997, the Safety Board stated that the actions taken to effectively coordinate the functions of the procedures development and flight inspection programs had satisfied the intent of the recommendation. Therefore, Safety Recommendation A-96-129 was classified "Closed — Acceptable Action."

Safety Recommendation A-96-131 asked the FAA to

> Include a more comprehensive set of guidelines concerning precipitous terrain adjustments in the Terminal Instrument Procedures (FAA Order 8260.3B) Handbook, clarifying the definition of precipitous terrain and establishing defined criteria for addressing the potential effect of such terrain.

On January 28, 1998, the FAA stated that it was developing a plan to revise the guidelines concerning precipitous terrain adjustments currently contained in the TERPS handbook. The FAA noted that it received appropriate funding and negotiated a contract with the National Center for Atmospheric Research to develop a plan to address this recommendation. The FAA expected that it would be provided with the findings of the center's effort by the end of fiscal year 1998. On April 15, 1998, the Safety Board indicated that it would await further information from the FAA.

On June 17, 1999, the FAA stated that it was continuing its efforts to revise the guidelines concerning precipitous terrain adjustments currently contained in the TERPS Handbook. According to the FAA, the National Center for Atmospheric Research developed a prototype software package that examines digital terrain elevation data from the Defense Mapping Agency's terrain elevation database. This software uses weighted parameters to determine if the terrain underlying the primary, secondary, and buffer area approach segments are high, steep, or rough enough to be considered precipitous. The output of this software specifies the minimum adjustment to the required obstacle clearance for precipitous terrain in each segment. The FAA indicated that the TERPS Handbook would be revised to require the use of this software in identifying precipitous terrain and determining the minimum required adjustment for such terrain. On August 20, 1999, the Safety Board stated that, pending final modification of the TERPS Handbook, Safety Recommendation A-96-131 was classified "Open — Acceptable Response."

Safety Recommendation A-96-132 asked the FAA to

> Review and evaluate the appropriateness of the let-down altitudes for all nonprecision approaches that have significant terrain features along the approach course between the initial approach fix and the runway. Airline safety departments and pilot labor organizations, such as the Allied Pilots Association and the Air Line Pilots Association, should be consulted as part of this review.

On December 30, 1997, the FAA said that it established a mandatory review for significant terrain features as part of its biennial review process. The FAA stated that Order 8260.19C, "Flight Procedures and Airspace," section 8, includes procedures for reviews of instrument procedures, which are to be conducted every 2 years or more frequently when deemed necessary. According to the FAA, the reviews are to be conducted in accordance with Order 8260.3B, "United States Standard Terminal Instrument Procedures (TERPS)," chapter 3, "Takeoff and Landing Minimums." Paragraph 323a, "Precipitous Terrain," states that "when procedures are designed for use in areas characterized by precipitous terrain, in or outside of designated mountainous area, consideration must be given to induced altimeter errors and pilot control problems which result when winds of 20 knots or more move over such terrain." The paragraph also states that, for areas in which these conditions are known to exist, the required obstacle clearance in the final approach segment should be increased.

The FAA added that Order 8260.19C stated that user comments should be solicited to obtain the best available local information to ensure that requirements for obstacle clearance, navigational guidance, safety, and practicality were met. The FAA also indicated that, on June 2, 1997, it reemphasized the procedures to be followed when conducting a periodic review of an instrument procedure. According to the FAA, the procedures require that obstacles, including terrain, be considered as potential precipitous terrain when developing or amending a standard instrument approach procedure and that these obstacles are to be evaluated and appropriate adjustments are to be made according to existing FAA orders and guidelines. The procedures also require that discussion and coordination with the users, airline safety departments, and pilot labor organizations are included in the review process.

On April 7, 1998, the Safety Board noted that the FAA had established a mandatory review for significant terrain features as part of its biennial review process. The Board also noted that the FAA had reemphasized that these procedures be followed when conducting a periodic review of an instrument procedure. Because these actions met the intent of Safety Recommendation A-96-132, it was classified "Closed — Acceptable Action."

Safety Recommendation A-96-133 asked the FAA to

> Solicit and record user comments about difficulties encountered in flying a particular approach to evaluate approach design accurately.

On February 24, 1997, the FAA stated that it would "invite airspace users to comment on dangerous approaches." On June 11, 1997, the FAA said that it had sent letters to various organizations, including the Allied Pilots Association, ALPA, the Air Transport Association, and the Aircraft Owners and Pilots Association, to request comments and concerns from their members regarding instrument flight procedures.

On September 8, 1997, the Safety Board stated that it had received copies of the letters from the industry organizations that had responded to the FAA's letter. Because the FAA's effort met the intent of Safety Recommendation A-96-133, it was classified "Closed — Acceptable Action."

1.18.5 Flight Crew Decision-making

1.18.5.1 Safety Board Study of Flight Crew Involvement in Major Accidents

In a 1994 safety study,[168] the Safety Board examined the operating environments and errors made by flight crewmembers in 37 major accidents between 1978 and 1990. The safety issues examined in the report included the performance of flight crews when the captain was the PF, the performance of the PNF in monitoring and challenging errors made by the PF, and the adequacy of CRM training programs.

The study concluded that the captain was the PF in more than 80 percent of the 37 accidents reviewed. This result was significant because U.S. air carrier flights during the study's time frame were divided about equally between those flown by the captain and those flown by the first officer.

The Safety Board identified 302 flight crew errors in the 37 accidents; the median number of errors per accident was 7. Of the total number of errors, 232 were considered primary errors, and 70 were considered secondary errors. The primary error categories identified by the Safety Board included aircraft handling, communication, navigational, procedural (for example, not conducting or completing required checklists or not following prescribed checklist procedures), resource management, situational awareness (for example, controlling the airplane at an incorrect target altitude), systems operation, and tactical decision (for example, improper decision-making, failing to change a course of action in response to a signal to do so, or failing to heed warnings or alerts that suggest a change in the course of actions). Secondary errors resulted from the failure of a crewmember to monitor or challenge a primary error made by the other crewmember. Table 4 shows the distribution of the 302 errors identified in the 37 accidents by type of error.

The Safety Board's study determined that procedural, tactical decision, and resource management errors were largely errors of omission and that navigational and most of the aircraft handling, communication, and systems operation errors were errors of commission. Of the 232 primary errors identified, 123 (53 percent) were errors of omission, and 109 (47 percent) were errors of commission.

The safety study also determined that captains were responsible for 168 of the 302 identified errors. Of the 168 errors made by captains, 49 (29 percent) were tactical decision errors, the most common error type attributed to captains. The 49 tactical decision errors made by captains accounted for 96 percent of the 51 tactical decision errors made by all crewmembers, which is consistent with the captain's ultimate responsibility for decisions. The study also found that procedural (23 percent) and aircraft Factual Information 121 Aircraft Accident Report handling (20 percent) were the next most common error types made by captains. The aircraft handling errors made by captains accounted for 33 (72 percent) of the 46 aircraft handling errors made by all crewmembers, which is consistent with the captain conducting the PF duties on more than 80 percent of the accident flights reviewed in the study.

Further, the study stated that a common pattern in 17 of the 37 accidents was a tactical decision error by the captain (more than one-half of which constituted a failure to initiate a required action) followed by the first officer's failure to challenge the captain's decision. The study also concluded that, of the 49 tactical decision errors made by captains, 44 (90 percent) were made while the captain was serving as the PF and that 26 (59 percent) of these errors were errors of omission. Thus, the most common tactical decision error was the failure of a captain serving as the PF to take action when the situation demanded change. In addition, of the 26 tactical decision errors made by captains that were errors of omission, 16 (62 percent) involved the captain's failure to execute a go-around during the approach. These 16 errors were made during 10 different accident sequences. Of the 16 failures to execute a go-around, 8 involved an unstabilized approach.

The study found that the 70 monitoring/challenging errors committed by flight crewmembers occurred in 31 (84 percent) of the 37 accidents reviewed in the study and that most of these errors played very important roles in the accidents. The study concluded that the highest percentage of the unmonitored/unchallenged errors were tactical decision errors (40 percent).

In addition, the study found that, of the 15 accidents for which information was available, 11 (73 percent) occurred during the first duty day together for the captain and first officer. Of the 16 accidents for which data were available, 7 (44 percent) occurred during the crewmembers' first flight together. According to the study, these rates are substantially higher than the percentage of crews who would be expected to be paired for the first time on any given flight or day.

Finally, the study examined the effect of the length of time since awakening (TSA) on the errors committed by flight crewmembers in the accident sequence. The performances of flight crews in which both the captain and the first officer had been awake a long time (average TSA length, 13.6 hours) were compared with flight crews in which both the captain and the first officer had been awake a short time (average TSA length, 5.3 hours). The Safety Board found that both the number and type of errors made by the flight crews varied significantly according to the TSA length. Specifically, high TSA crews made an average of 40 percent more errors (almost all of which were errors of omission) than low TSA crews.

High TSA crews made significantly more procedural errors and tactical decision errors than low TSA crews. These results

Table 4. Distribution of errors identified in the 37 accidents reviewed in the Safety Board's 1994 safety study.

Type of error	Number	Percent	Number of accidents
Primary error			
Aircraft handling	46	15.2	26
Communication	13	4.3	5
Navigational	6	2.0	3
Procedural	73	24.2	29
Resource management	11	3. 6	9
Situational awareness	19	6.3	12
Systems operation	13	4.3	10
Tactical decision	51	16.9	25
Secondary error			
Monitoring/challenging	70	23.2	31

suggested that the degraded performance by high TSA crews tended to involve ineffective decision-making (such as failing to perform a missed approach) and procedural slips (such as not making altitude awareness callouts) rather than a deterioration of aircraft handling skill. Also, the number and types of errors made by the flight crews varied according to the TSA length before the accident. The median TSA periods were quite high: 12 hours for captains and 11 hours for first officers. Those pilots who had been awake longer than the median TSA length for their crew position made more decision-making errors and procedural errors than pilots who had been awake for less time.[169]

1.18.5.2 Previous Safety Recommendations on Flight Crew Decision-making

On the basis of the findings of its safety study, the Safety Board issued Safety Recommendations A-94-3 and A-94-4 on February 3, 1994. Safety Recommendation A-94-3 asked the FAA to

> Require U.S. air carriers operating under 14 CFR Part 121 to provide, for flight crews not covered by the Advanced Qualification Program, line operational simulation training during each initial or upgrade qualification into the flight engineer, first officer, and captain position that (1) allows flight crews to practice, under realistic conditions, nonflying pilot functions, including monitoring and challenging errors made by other crewmembers; (2) attunes flight crews to the hazards of tactical decision errors that are errors of omission, especially when those errors are not challenged; and (3) includes practice in monitoring and challenging errors during taxi operations, specifically with respect to minimizing procedural errors involving inadequately performed checklists.

On April 26, 1994, the FAA stated that it was amending AC 120-51A, "Crew Resource Management," to emphasize the areas detailed in the recommendation. On July 6, 1994, the Safety Board noted that including the recommendation's material in an AC would be an acceptable alternative to regulatory change. However, on May 8, 1995, the Safety Board expressed disappointment that the revised AC 120-51B (issued on January 3, 1995) made no specific reference to practicing PNF procedures, such as monitoring and challenging the errors of the other pilots, during line-oriented simulation training. Likewise, the AC contained no specific references to line-oriented simulation training in the areas of monitoring and challenging tactical decision errors or inadequately performed taxi checklist procedures.

On September 8, 1995, the FAA issued a revision (Change 2) to AC 120-51B. On January 16, 1996, the Safety Board stated that the revised AC's reference to line operational simulation was responsive to all aspects of Safety Recommendation A-94-3. The provisions for PNF functions, monitoring and challenging of errors made by other crewmembers, tactical decision errors that are errors of omission, and errors made during taxi operations would achieve the Board's objectives as an alternative to the regulatory change that was originally proposed. Therefore, Safety Recommendation A-94-3 was classified "Closed — Acceptable Alternate Action."

Safety Recommendation A-94-4 asked the FAA to

> Require that U.S. air carriers operating under 14 CFR Part 121 structure their initial operating experience programs to include (1) training for check airmen in enhancing the monitoring and challenging functions of captains and first officers; (2) sufficient experience for new first officers in performing the nonflying pilot role to establish a positive attitude toward monitoring and challenging errors made by the flying pilot; and (3) experience (during initial operating experience and annual line checks) for captains in giving and receiving challenges of errors.

On April 26, 1994, the FAA stated that its actions in response to Safety Recommendation A-94-3 addressed the issues referenced in this recommendation. On July 6, 1994, the Safety Board reiterated that one intent of Safety Recommendation A-94-4 was for air carriers to provide crewmembers undergoing initial operational experience (IOE) with experience specifically in the PNF role. The Safety Board believed that the FAA should, at the very least, provide guidance to air carriers on this issue in the form of an AC.

On February 28, 1995, the FAA informed the Safety Board that, on January 3, 1995, AC 120-51B, "Crew Resource Management," was issued to provide emphasis for the PNF to monitor and challenge errors and for the PF to give and receive challenges of errors. On April 24, 1995, the Safety Board expressed its disappointment that AC 120-51B made no reference to the structure of IOE, PNF experience in monitoring and challenging errors during IOE and LOFT, or experience for captains in giving and receiving challenges of errors.

On June 16, 1995, the FAA stated that, on April 21, 1995, it had issued a final rule to amend the pilot qualification requirements for air carrier and commercial operators. According to the FAA, the final rule requires that second-in-command pilots obtain operating experience while performing the duties of a second-in-command under the supervision of a qualified pilot check airman. Additionally, the FAA stated that it was revising AC 120-51B to provide emphasis on the role of the PNF in monitoring and challenging errors and for captains to gain experience in giving and receiving challenges of errors. The FAA indicated that the revisions to the AC would emphasize the training of check airmen so that they would be prepared to enhance the monitoring and challenging functions of captains and first officers.

On August 29, 1995, the Safety Board stated that it was pleased that the FAA had issued a final rule that required air carriers to provide newly qualified second-in-command pilots with IOE while actually performing the duties of, rather than while observing, a second-in-command pilot. The Board was also pleased that the FAA was revising AC-120-51B. The Board believed that check airmen who receive training in enhancing the monitoring and challenging functions of captains and first officers would be able to provide more effective operating experience for newly qualified pilots if air carrier IOE programs ensured that pilots receive sufficient experience performing PNF functions while under check airman supervision.

On November 17, 1995, the FAA informed the Safety Board that it had revised AC-120B. On January 16, 1996, the Safety Board stated that the revised AC's reference to training for check airmen in methods that could be used to enhance the monitoring and challenging function of captains and first officers was responsive to Safety Recommendation A-94-4 because the check airmen would apply their CRM skills during IOE for new captains and first officers. Because the FAA's revisions to AC 120-51B satisfied the intent of Safety Recommendation A-94-4, it was classified "Closed — Acceptable Alternate Action."

1.18.5.3 National Aeronautics and Space Administration's Flight Crew Decision-making Study

Researchers at the National Aeronautics and Space Administration's (NASA) Ames Research Center conducted a study that examined the Safety Board's findings in its 1994 safety study (see section 1.18.5.1). The purpose of the NASA study was to analyze the accident data to identify any contributing factors such as "ambiguous dynamic conditions and organizational and socially-induced goal conflicts."[170]

The NASA researchers reexamined the 37 accidents included in the safety study to determine the most common decision errors and any themes or patterns in the context within which the errors occurred. NASA found that the most common decision errors occurred when the flight crew decided to "continue with the original plan of action in the face of cues that suggested changing the course of action." The NASA study stated:

> Clearly, more cognitive effort is needed to revise one's understanding of a situation or to consider a new course of action than sticking with the original plan whose details have already been worked out … . It appears that evidence must be unambiguous and of sufficient weight to prompt a change of plan.

With regard to ambiguity and its effect on situation assessment and decision-making, the NASA study stated:

> Cues that signal a problem are not always clear-cut. Conditions can deteriorate gradually, and the decision maker's situation assessment may not keep pace … a recurring problem is that pilots are not likely to question their interpretation of a situation even if it is in error. Ambiguous cues may permit multiple interpretations. If this ambiguity is not recognized, the crew may be confident that they have correctly interpreted the problem. Even if the ambiguity is recognized, a substantial weight of evidence may be needed to change the plan being executed.

The study noted that stress may limit the pilot's ability to properly evaluate the situation:

> Reaching decision … requires projection and evaluation of the consequences of the various options. If pilots are under stress, they may not do the required evaluations … . Under stress, decision makers often fall back on their most familiar responses, which may not be appropriate to the current situation.

Further, the NASA study determined that organizational and social pressures may contribute to the high incidence of "plan continuation errors" by creating goal conflicts, which may result in decision errors in the face of ambiguous cues and high-risk situations. The study noted that organizational and social factors that have the potential to create goal conflicts with safety include pressure for on-time arrival rates, fuel economy, and avoidance of diversions to reduce passenger inconvenience.

The NASA study concluded that, to reduce pressures on pilots, operators "must be willing to stand behind their pilots who take a safe course of action rather than a riskier one, even if there is a cost associated." The study noted that integrated flight displays that present up-to-date information on dynamic variables, such as weather and traffic, could reduce the ambiguity of events flight crews might encounter and that training to help flight crews develop "strategies for choosing a course of action" would be beneficial.

1.18.6 Previous Fatigue-Related Accidents

The Safety Board has investigated several accidents in which fatigue was either the cause or a contributing factor. A discussion of two such accidents follows.

Continental Express Jet Link Flight 2733

On April 29, 1993, Continental Airlines (d.b.a. Continental Express) Jet Link flight 2733, an Embraer EMB-120RT, N24706, crashed at Pine Bluff, Arkansas, during a forced landing and runway overrun at a closed airport.[171] The flight was a scheduled 14 CFR 135 operation from Little Rock, Arkansas, to Houston, Texas. The 2 flight crewmembers and 15 passengers were uninjured, and the flight attendant and

12 passengers received minor injuries. The accident occurred on the third day of a 3-day trip sequence, and the accident flight was the seventh and last flight of the day.

As the airplane was climbing, the captain, who was the PF, increased pitch so that the flight attendant could begin cabin service. The autoflight was set in pitch and heading modes, contrary to company policy. The airplane stalled in IMC at 17,400 feet. Initial recovery was at 6,700 feet. Because of an improper recovery procedure, a second stall occurred, and recovery was at 5,500 feet. The left propeller shed three blades, the left engine cowling separated, and the left engine was shut down in descent. Level flight could not be maintained, and a forced landing was made. The captain overshot the final turn because of controllability problems, and the airplane landed fast with 1,880 feet of wet runway remaining. The airplane hydroplaned off the runway and received additional damage. No preaccident malfunction was found.

The Safety Board's review of the captain's schedule revealed that the first day of the trip involved 9.5 hours of duty time followed by 8.5 hours of rest time (a reduced rest period). The second day of the trip involved 3.8 hours of duty time. The captain was off duty at 1130 but did not go to sleep until between midnight and 0030.[172] On the third day of the trip, the captain awoke about 0500 for an early duty time. At the time of the accident, the captain had been awake for about 11 hours.

The first officer's flight, duty, and crew rest schedules were the same as that of the captain for the 3-day trip sequence. The first officer went to bed between 2300 and midnight on the night before the accident and awoke about 0430 on the day of the accident. The first officer had also been awake about 11 hours at the time of the accident.

The Safety Board determined that the probable cause of the accident was the captain's failure to maintain professional cockpit discipline, his consequent inattention to flight instruments and ice accretion, and his selection of an improper autoflight vertical mode, all of which led to an aerodynamic stall, loss of control, and a forced landing. A factor contributing to the accident was fatigue induced by the flight crew's failure to properly manage provided rest periods.[173]

American International Airways Flight 808

On August 18, 1993, American International Airways (d.b.a. Connie Kalitta Services, Inc.) flight 808, a Douglas DC-8-61, N814CK, was on a nonscheduled 14 CFR Part 121 operation when it crashed in at the U.S. Naval Air Station at Guantanamo Bay, Cuba.[174] The cargo airplane collided with level terrain approximately 1/4 mile from the approach end of runway 10 at Leeward Point Airfield after the captain lost control of the airplane. The airplane was destroyed by impact forces and a postcrash fire, and the three flight crew members — the only occupants aboard the airplane-received serious injuries. The cargo airplane was on the last leg of a flight sequence that day from Atlanta, Georgia, to Norfolk, Virginia, and then Guantanamo Bay.

The flight crew had been on duty about 18 hours and had flown approximately 9 hours.[175] The captain did not recognize deteriorating flightpath and airspeed conditions because of his preoccupation with locating a strobe light[176] on the ground. The flight engineer made repeated callouts regarding slow airspeed conditions. The captain initiated a turn on final approach at an airspeed below the calculated approach speed of 147 knots and less than 1,000 feet from the shoreline, and the captain allowed bank angles in excess of 50° to develop. The stall warning stickshaker activated 7 seconds before impact and 5 seconds before the airplane reached stall speed. No evidence indicated that the captain attempted to take proper corrective action at the onset of the stickshaker. The Safety Board concluded that the substandard performance by this experienced pilot may have reflected the debilitating influences of fatigue.

In its report on this accident, the Safety Board stated that three background factors are commonly examined for evidence related to fatigue: cumulative sleep loss, continuous hours of wakefulness, and time of day. The flight crew had received limited sleep in the 48 hours before the accident because of flight and duty time. Also, at the time of the accident, the captain had been awake for 23.5 hours, the first officer for 19 hours, and the flight engineer for 21 hours. In addition, the accident occurred about 1656 eastern daylight time (based on a 24-hour clock), at the end of one of the two low periods in a person's circadian rhythm. The Board also considered the captain's self-report (for example, his report of feeling "lethargic and indifferent" in the last period before the accident) in evaluating whether fatigue was present.

The Safety Board determined that the probable cause of the accident was the impaired judgment, decision-making, and flying abilities of the captain and the other flight crewmembers because of the effects of fatigue; the captain's failure to properly assess the conditions for landing and maintaining vigilant situational awareness of the airplane while maneuvering onto final approach; his failure to prevent the loss of airspeed and avoid a stall while in the steep bank turn; and his failure to execute immediate action to recover from a stall. Additional factors contributing to the cause of the accident included the inadequacy of the flight and duty time regulations applied to 14 CFR Part 121 supplemental air carriers, international operations, and the circumstances that resulted in the extended flight and duty hours and fatigue of the flight crewmembers.

1.18.6.1 Previous Safety Recommendations Regarding Fatigue

On May 17, 1999, the Safety Board adopted a safety report entitled *Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue*.[177] In its report, the Board noted that in 1989 it issued three recommendations to the DOT addressing needed research, education, and revisions to hours-of-service regulations.[178] The Board further noted that, since that time, it had issued more than 70 additional recommendations aimed at reducing the incidence of fatigue-related accidents. The Board stated that, even though the DOT and modal administrations had responded positively to the recommendations addressing research and education, little action had occurred with respect to revising the hours-of-service regulations.

The safety report discussed the activities and efforts by the DOT and the modal administrations to address operator fatigue and the resulting progress that has been made over the past 10 years to implement the actions called for in the Safety Board's fatigue-related recommendations. The report also provided background information on current hours-of-service regulations, fatigue, and the effects of fatigue on transportation safety. As a result of its findings, the Safety Board issued Safety Recommendations I-99-1 and A-99-45.

Safety Recommendation I-99-1 asked the DOT to

> Require the modal administrations to modify the appropriate *Codes of Federal Regulations* to establish scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. Seek Congressional authority, if necessary, for the modal administrations to establish these regulations.[179]

Safety Recommendation A-99-45 asked the FAA to

> Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements.

On July 15, 1999, the FAA indicated that it agreed with the intent of Safety Recommendation A-99-45 and stated that, on December 11, 1998, it had issued NPRM 95-18, which proposed amending existing regulations to establish one set of duty period limitations, flight time limitations, and rest requirements for flight crewmembers engaged in air transportation. The FAA stated that the NPRM considered scientific data from studies conducted by NASA relating to flight crewmember duty periods, flight times, and rest and that Safety Recommendation A-99-45 would be included in this rulemaking project. The FAA further indicated that its Aviation Rulemaking Advisory Committee was tasked to review reserve issues related to the NPRM but was unable to agree on a recommendation. The FAA indicated that it was conducting a risk assessment to determine the probability of preventing future incidents related to fatigue and did not know when a supplemental NPRM would be issued. However, the FAA stated that, in the interim, it published a notice on June 15, 1999, indicating its intent to enforce the regulations concerning flight time limitations and rest requirements. At an October 7, 1999, meeting with the Safety Board's Chairman, the FAA Administrator indicated that a final rule would not be issued within the next 2 years.

1.18.7 Flight Data Recorder Documentation

A digital flight data recorder (DFDR) records values for parameters related to the operation of an airplane (for example, altitude, airspeed, and heading). The values are recorded in a serial binary digital data stream that must be converted either to engineering units or discrete states. The arrangement of the recorded values often varies among DFDR systems; consequently, accurate conversion of the recorded values to their corresponding engineering units or discrete states can be accomplished only when the configuration of the data has been thoroughly documented.

1.18.7.1 Previous Safety Board Recommendations on Flight Data Recorder Parameter Verification and Documentation

In the early 1970s, the Safety Board began issuing safety recommendations to improve FDR parameter verification and documentation. In 1991, the Safety Board issued two safety recommendations (A-91-23 and -24) to the FAA for developing a permanent policy for FDR maintenance and record-keeping. In 1997, after a series of accidents that involved problems with extracting data from retrofitted FDRs, the Safety Board issued a safety recommendation (A-97-30) that asked the FAA to publish an AC addressing the certification and maintenance of FDRs.[180]

Safety Recommendation A-91-23 asked the FAA to

> Issue permanent policy and guidance material for the continued airworthiness of digital flight data recorder systems, stating that the make and model of the flight data recorder and the make and model of the flight data acquisition unit, if installed, must be maintained as part of each aircraft's records, as well as at least the following information for each parameter recorded:
>
> - Location of parameter word (2 through 64 or 128).
> - Assigned bits (1 through 12).
> - Range (in engineering units when applicable).
> - Sign convention (for example, trailing edge up = +).
> - Type sensor (for example, synchro or low-level DC).
> - Accuracy limits (sensor input).

- FAA requirement (that is, mandatory or not mandatory).

- Subframe/superframe assignment: Documentation for engineering unit conversion.

- General equation: Provide A0, A1, A2, and A3 for the equation $Y = A0 + A1X + A2X2 + A3X3$, where Y = output in engineering units and X = input in decimal or converted counts.

- Nonlinear parameters: Provide a sufficient number of data samples (engineering units versus recorded decimal counts) to develop a conversion algorithm that will accurately define the full range of the parameter.

- Discrete parameters: Status (that is, 1 = on, 0 = off).

Safety Recommendation A-91-24 asked the FAA to

> Require operators to maintain current information for each unique digital flight data recorder configuration in its inventory using a single, universally adopted format, such as that described in the standard being developed by Aeronautical Radio, Inc.

On May 9, 1991, the FAA stated that it was reviewing these safety recommendations. On August 1, 1991, the Safety Board stated that it was disappointed that the FAA failed to include any timetable for the completion of the review because untimely or missing DFDR documentation was adversely affecting ongoing investigations. The Board reemphasized its commitment to these recommendations, stating that it would continue to work with the FAA and the aviation industry to implement the recommendations.

On December 18, 1991, the FAA stated that it was planning to develop an AC to address the installation and maintenance of DFDRs and flight data acquisition units (FDAU). The FAA indicated that the AC would reference the appropriate regulatory requirements and contain the universal documentation format for each DFDR aircraft configuration and installation. The FAA further indicated that the baseline documents for the AC would be the universal format being developed by Aeronautical Radio, Inc., and the Board's proposed FDR configuration documentation standard.

On January 28, 1992, the Safety Board stated that it remained encouraged by the FAA's support for these safety recommendations. The Board believed that the FAA's plan to develop an AC that addresses the installation and maintenance of DFDR systems and references a universal documentation standard was a step in the right direction. However, the Board believed that the AC needed to be supplemented with permanent policy and guidance material so that FAA inspectors would require that the AC be implemented.

On April 22, 1994, the Safety Board stated that, in early 1993, FAA staff had indicated that the proposed AC had not been developed because the FAA was waiting for Aeronautical Radio, Inc., to publish the proposed documentation standard. Because Aeronautical Radio was unable to commit the resources needed to publish the proposed standard, the FAA proposed that the Board draft an AC that incorporated the draft Aeronautical Radio documentation standard. Safety Board and FAA staffs subsequently discussed and agreed on the principal elements of a draft AC based on the draft Aeronautical Radio documentation standards. On October 18, 1993, the Board provided a draft of the AC and DFDR documentation standards. However, the FAA made no progress toward implementing Safety Recommendations A-91-23 and -24, even with the Board's draft AC. The Safety Board continued to believe that the actions requested in these recommendations were essential and therefore urged the FAA to take the necessary actions.

On March 3, 1997, the FAA stated that it included information regarding the installation and maintenance of DFDRs and FDAUs in Notice N8110.65, "Policy and Guidance for the Certification and Continued Airworthiness of Digital Flight Data Recorder Systems." According to the FAA, the notice referenced the appropriate regulatory requirements and contained the universal documentation format for each DFDR aircraft configuration and installation. The FAA stated that the universal format developed by Aeronautical Radio, Inc., and the Board's proposed FDR configuration documentation standard were used as baseline documents for the notice.

On July 10, 1998, the Safety Board noted its disappointment that the AC had still not been completed. The Board stated that inclusion of guidance relating to FDR Information 132 Aircraft Accident Report maintenance documentation (which was addressed in FAA Notice N8110.65) in this AC would satisfy the intent of Safety Recommendations A-91-23 and -24, which had been issued 7 years earlier. The Board was concerned that the AC might still not be produced in a timely manner. Accordingly, the Safety Board classified Safety Recommendations A-91-23 and -24 "Open — Unacceptable Response" pending the FAA's completion of the AC.

Safety Recommendation A-97-30 asked the FAA to

> Complete the planned flight data recorder (FDR) advisory circular (AC) to define FDR certification requirements and FDR maintenance requirements, and incorporate the FDR documentation standards contained in Notice N8110.65. The AC should be released no later than January 16, 1998.

On July 14, 1997, the FAA stated that it agreed with the intent of this safety recommendation. The FAA also stated that it would complete the AC for FDR certification and maintenance requirements by January 1998.

On July 10, 1998, the Safety Board stated its disappointment that the AC, promised by the FAA to be issued by January 1998, had not been completed. The Board was concerned that the AC would not be produced in a timely manner. The Board stated that the guidance contained in this AC was essential to avoid widespread retrofit problems.[181] Pending the FAA's completion of the AC, the Safety Board classified Safety Recommendation A-97-30 "Open — Unacceptable Response."

1.18.7.1.1 Digital Flight Data Recorder Advisory Circular

On October 5, 1999, AC 20-141, "Airworthiness and Operational Approval of Digital Flight Data Recorder Systems," was issued. The purpose of the AC is to provide "guidance on design, installation, and continued airworthiness of Digital Flight Data Recorder Systems." Appendix 1 to the AC, titled "Standard Data Format for Digital Flight Data Recorder Data Stream Format and Correlation Documentation," provides "a standard for the data stream format and correlation documentation that operators must maintain to aid accident investigators in interpreting recorded flight data." The appendix details how to develop a document for each airplane that would provide in detail the information that would assist Safety Board investigators in transcribing each parameter recorded by an FDR.

1.18.7.2 International Guidance Regarding the Documentation of Flight Data Recorder Parameters

ICAO provides guidance to Member States regarding the documentation of FDR parameters. ICAO Annex 6, "International Standards and Recommended Practices — Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes," includes Attachment D, Flight Recorders. Section 3 of the attachment, "Inspections of flight data and cockpit voice recorder systems," provides guidance on the continued airworthiness of FDR systems, including how to conduct annual checks of every FDR parameter. Paragraph 3.2(c) states that "a complete flight from the FDR should be examined in engineering units to evaluate the validity of all recorded parameters." In addition, paragraph 3.2(d) states that "the readout facility should have the necessary software to accurately convert the recorded values to engineering units and to determine the status of discrete signals."

1.18.8 Special Airport Criteria and Designation

On October 19, 1996, Delta Air Lines flight 554, a McDonnell Douglas MD-88, N914DL, struck the approach light structure at the end of the runway deck during the approach to land on runway 13 at LaGuardia Airport in Flushing, New York.[182] IMC conditions prevailed for the ILS DME approach. None of the two flight crewmembers and three flight attendants were injured, but 3 of the 58 passengers received minor injuries. The airplane sustained substantial damage.

According to the first officer of the flight, the approach to runway 13 requires landing over water, a 250-foot DH, and an offset localizer, and the approach to the opposite direction runway (31) requires maneuvering an airplane at high bank angles close to the ground. However, LaGuardia was not designated by the FAA as a special airport under 14 CFR Section 121.445.[183] That section, titled "Pilot in command airport qualification: Special areas and airports," states the following:[184]

> (a) The [FAA] Administrator may determine that certain airports (due to items such as surrounding terrain, obstructions, or complex approach or departure procedures) are special airports requiring special airport qualifications and that certain areas or routes, or both, require a special type of navigation qualification.
>
> (b) … no certificate holder may use any person, nor may any person serve, as pilot in command to or from an airport determined to require special airport qualifications unless, within the preceding 12 calendar months:
>
>> (1) The pilot in command or second in command has made an entry to that airport (including a takeoff and landing) while serving as a pilot flight crewmember; or
>>
>> (2) The pilot in command has qualified by using pictorial means acceptable to the Administrator for that airport.

The Safety Board's investigation of the accident concluded, among other things, that the FAA's guidance on special airports was not sufficiently specific about criteria and procedures for designation of special airports; therefore, the FAA's guidance might not always be useful to air carriers operating in and out of special airports. The Board also concluded that the requirements for special airport pilot qualifications might not be sufficient to ensure that qualified pilots have been exposed to the runways and/or approaches that make those airports "special."

As a result of its findings, the Safety Board issued Safety Recommendations A-97-92 through -94 on August 25, 1997. Safety Recommendations A-97-92 through -94 asked the FAA to

> Expedite the development and publication of specific criteria and conditions for the classification of special airports; the resultant publication should include specific remarks detailing the reason(s) an airport is determined to be a special airport and procedures for adding and removing airports from special airport classification. (A-97-92)

> Develop criteria for special runways and/or special approaches, giving consideration to the circumstances of this accident and any unique characteristics and special conditions at airports … and include detailed pilot qualification requirements for designated special runways or approaches. (A-97-93)
>
> Once criteria for designating special airports and special runways and/or special approaches have been developed, as recommended in Safety Recommendations A-97-92 and -93, evaluate all airports against that criteria and update special airport publications accordingly. (A-97-94)

On November 13, 1997, the FAA stated that it was developing a flight standards handbook bulletin and revising AC 121.445, "Pilot-In-Command Qualifications for Special Area/Routes and Airports, Federal Aviation Regulations (FAR) Section 121.445."[185] The FAA indicated that the bulletin and AC would address the issues discussed in the recommendations. The FAA anticipated that these documents would be issued in April 1998. On August 17, 1998, the Safety Board stated that, pending the FAA's completion of these documents, Safety Recommendations A-97-92 through -94 were classified "Open — Acceptable Response."

On September 21, 1999, the FAA stated that AC 121.445 was undergoing internal coordination and should be published in the Federal Register by November 1999. The FAA indicated that it would proceed with issuing the flight standards handbook bulletin as soon as the AC was completed. According to the FAA, both documents were expected to be issued by February 2000.

2. Analysis

2.1 General

The three Korean Air flight 801 flight crewmembers were properly certificated and qualified in accordance with applicable Korean Civil Aviation Bureau (KCAB) and U.S. Federal regulations, International Civil Aviation Organization (ICAO) standards, and Korean Air company requirements. No evidence indicated that any medical factors affected the flight crew's performance.

The airplane was properly certificated, equipped, and maintained in accordance with applicable KCAB and ICAO standards and Korean Air company procedures. The airplane was authorized to operate in U.S. airspace under the provisions of 14 Code of Federal Regulations (CFR) Part 129. The weight and balance of the airplane were within the prescribed limits for landing. No evidence indicated that the airplane experienced preimpact failures of its structures, flight control systems, or engines.

ATC personnel involved with the flight were properly certificated and qualified as full-performance level controllers. ATC radar and communications equipment were found to be functioning properly, although the FAA-maintained minimum safe altitude warning (MSAW) system had been intentionally inhibited.

This analysis examines the accident scenario, including weather factors, flight crew performance and decision-making, and other relevant factors during the approach, as well as flight crew fatigue issues. The analysis also examines the performance of ATC personnel, the effects of the MSAW system's intentional inhibition, and the timeliness and effectiveness of the emergency response to the accident site. In addition, the analysis examines Korean Air's flight crew simulator training, KCAB oversight of Korean Air's flight training programs, FAA oversight of Korean Air's operations under 14 CFR Part 129, and international efforts to reduce the number of controlled flight into terrain (CFIT) accidents.

2.2 Weather Factors on the Approach

A review of weather data indicated that variable clouds and scattered rain showers associated with a weak eastward-moving low-pressure trough were affecting the Guam area about the time of the accident and that the showers increased in intensity as they moved over the higher terrain of the island. However, Safety Board interviews with flight crewmembers who flew into Guam before and after the flight 801 accident indicated that the lights of the island were occasionally visible from as far away as 150 nm. In addition, CVR data indicated that the accident flight crew made visual contact with the island about 16 minutes before the accident (about 0126:25) when the flight engineer stated "it's Guam, Guam."

On the basis of weather data and witness statements, flight 801 was likely to have initially encountered variable scattered to broken cloud layers below 5,000 feet msl during the final approach to Guam. Ground lights were likely occasionally visible along the coastline, and it is probable that only scattered clouds existed below the airplane in the vicinity of the FLAKE intersection, located 7 DME from the NIMITZ VOR (UNZ).

Doppler radar data indicated that a heavy to very heavy rain shower was centered over higher terrain about 4 nm southwest of the airport (along the approach corridor) about the time of the accident. Weather data indicated that, although the Apra Harbor area (about 5 DME on the approach course) would likely have been visible to the flight crew as the airplane descended through 2,000 feet msl, the airplane would have entered clouds and light precipitation shortly after passing Apra Harbor. Radar data indicated that the flight likely experienced rain of continuously increasing intensity as the airplane proceeded inbound toward the airport and that the flight encountered very heavy precipitation for a short time near the outer marker (GUQQY). About 0141:48, when the airplane was near the outer marker, the CVR recorded the captain stating "wiper on."

Although a hunter on Nimitz Hill stated that it was not raining at the time he observed the flight overhead, Doppler radar data indicated light to moderate rain shower activity between Nimitz Hill and the airport. Therefore, on the basis of weather radar and observation data, the Safety Board concludes that, after the flight crew made an initial sighting of Guam, Korean Air flight 801 encountered instrument meteorological conditions (IMC) as the flight continued on its approach to Guam International Airport. Further, the Safety Board concludes that, although flight 801 likely exited a heavy rain shower shortly before the accident, the flight crew was still not able to see the airport because of the presence of another rain shower located between Nimitz Hill and the airport.

2.3 Accident Sequence

2.3.1 Description of the Approach and Required Flight Crew Procedures

The instrument landing system (ILS) glideslope (GS) inoperative, or localizer (LOC)-only, approach to runway 6L at Guam International Airport required the flight crew to maintain at least 2,000 feet from the FLAKE intersection (7 DME from the UNZ VOR) to the GUQQY (outer marker) final approach fix (FAF), which was located 1.6 DME from the UNZ VOR. After passing GUQQY, the crew was required to maintain at least 1,440 feet msl until passing the UNZ VOR. After passing the UNZ VOR, the next step-down fix was to 560 feet (the minimum descent altitude [MDA]), and the flight crew was required to maintain at least this altitude while counting up to 2.8 DME (the missed approach point [MAP]) from the UNZ VOR.

To properly fly this approach, the flying pilot's navigation receiver would need to be tuned to the localizer frequency, and the nonflying pilot's navigation receiver would need to be tuned to the UNZ VOR to provide the pilots with DME information for FLAKE, GUQQY, and the MAP and allow them to identify station passage over the UNZ VOR. Station passage over UNZ would be marked by the following instrument indications: the TO/FROM indicator in the first officer's horizontal situation indicator (HSI) would have changed from TO to FROM, and the No. 2 (double) pointer in the captain's and first officer's radio magnetic indicator would have swung from pointing forward to aft. Although station passage is not defined by DME, station passage over the UNZ VOR would have been indicated by a DME countdown to near zero and then a count up as the airplane continued away from UNZ to runway 6L.

To use the autopilot and flight director (FD) during a nonprecision approach, the flying pilot would have set the Nav Mode Switch to VOR/LOC on the glareshield instrument panel once the airplane was established on the intercept heading to the localizer outside the FAF. The FD and autopilot flight mode annunciator (FMA) on the pilots' instrument panels would then indicate NAV armed and GS blank.[186] After localizer capture, the pilots' and the autopilot's FMAs would indicate NAV capture,[187] and the GS would remain blank. The autopilot would turn the airplane as needed to track the localizer. (Although the nonflying pilot's navigation receiver would be tuned to the VOR, a different frequency, that pilot's FMA would also indicate NAV capture because the UNZ 243° radial approximately overlays the localizer.) The FD command bars on the captain's and the first officer's instruments would provide left and right roll commands to maintain a capture on the respective courses.

When the airplane was descending, the flying pilot would normally have reset the altitude selector to the next (lower) altitude target and moved the VERT SPEED (vertical speed) wheel to position the airplane in about a 1,000-feet-per-minute rate of descent to reach the next crossing altitude. The FD pitch command bars would move up and down to provide guidance to maintain the desired rate of descent. (In a precision approach, the command bars would provide guidance to maintain the glideslope; in nonprecision approaches, they provide guidance to maintain the desired vertical speed.) Once the airplane had reached the altitude set in the altitude selector, the FDs and autopilot would capture and maintain that altitude. At no time during the localizer approach would the flight crew have armed the autopilot or FDs to capture a glideslope signal or have referenced or attempted to track any glideslope needle indications.

2.3.2 Flight 801's Premature Descent

The Combined Center/Radar Approach Control (CERAP) controller vectored flight 801 to join the runway 6L localizer course between the FLAKE intersection and the GUQQY outer marker/1.6 DME fix. Although the flight was restricted to no lower than 2,000 feet msl in that portion of the localizer-only approach procedure (until crossing the GUQQY outer marker), flight 801 descended below 2,000 feet about 1.9 nm before reaching the outer marker.

Further, although the approach procedure specified that at least 1,440 feet msl should be maintained after passing the GUQQY outer marker and until passing the UNZ VOR, flight 801 descended below 1,440 feet about 2.1 DME before reaching the UNZ VOR. (None of the indications of UNZ station passage would have been presented on the flight crew's instrument panels at any time before impact.)

CVR information indicated that the captain was flying the airplane on autopilot during the approach. As flight 801 descended on the approach, the captain twice commanded the entry of lower altitudes into the airplane's altitude selector before the airplane had reached the associated step-down fix. After the captain heard the first officer call out "approaching fourteen hundred [feet]" about 0140:33, as the airplane was passing 5 DME at 2,400 feet msl,[188] the captain directed the first officer to reset the altitude selector to 1,440 feet, replacing the step-down altitude of 2,000 feet before the autopilot had captured that altitude or reached the GUQQY outer marker/1.6 DME fix. Further, about 0141:33, with the flight neither having leveled off at 1,440 feet msl nor reached the UNZ VOR step-down fix, the captain instructed the first officer to set 560 feet, the MDA, in the altitude selector.

The altitude selector provides the basis for the altitude alert's aural annunciations and the autopilot's altitude capture functions. The captain's premature orders to reset the altitude selector indicated that he had lost awareness of the airplane's position along the final approach course. Therefore, as a result of the captain's commanded input to the altitude selector, the autopilot continued to descend the airplane prematurely through the 2,000- and 1,440-foot intermediate altitude constraints of the approach procedure. The CVR comments indicated no awareness by the captain that the airplane was descending prematurely below the required intermediate altitudes.

2.4 Flight Crew Performance

2.4.1 The Captain's Performance of the Approach

2.4.1.1 Approach Briefing

Korean Air cockpit procedures call for an approach (landing) briefing[189] before descent. Also, company training instructs the flying pilot to conduct an approach briefing before descent. According to the Korean Air 747 landing briefing checklist card and testimony by Korean Air officials during the Safety Board's public hearing, this briefing should include a discussion of weather conditions, a review of the instrument approach procedure, details of the approach's execution (including the minimum safe altitude, approach frequency and approach course, the runway touchdown zone elevation, and the missed approach procedure), crew actions and callouts, and any abnormal configurations or conditions.

CVR information indicated that the captain briefed a visual approach in his approach briefing, which he referred to as a "short briefing." However, the captain also briefed some elements of the localizer-only instrument approach, indicating that he intended to follow that approach as a supplement or backup to the visual approach. Specifically, the captain's briefing included a reminder that the glideslope was inoperative, some details of the radio setup, the localizer-only MDA, the missed approach procedure, and the visibility at Guam (stated by the captain to be 6 miles). However, the captain did not brief other information about the localizer-only approach, including the definitions of the FAF and step-down fixes and their associated crossing altitude restrictions or the title, issue, and effective dates of the approach charts to be used. The Safety Board notes that the landing briefing checklist did not specifically require the captain to brief the fix definitions, crossing altitudes, or approach chart title and dates,[190] although it would have been good practice to do so.

Further, according to public hearing testimony by a Korean Air instructor pilot, company pilots were trained to conduct a more detailed briefing than the one specified in the landing briefing checklist for a nonprecision approach, such as the localizer approach to runway 6L at Guam. According to the instructor pilot, this more detailed briefing included a discussion of the "instrument approach in detail" and a discussion of the "step-down altitudes and how they were determined." The Safety Board notes that this information is essential for a nonprecision approach briefing.

The Safety Board also notes that the captain did not brief the first officer and flight engineer on how he would fly the descent (including his planned autopilot/FD modes and his plan to fly either a constant angle of descent or a series of descents and level-off altitudes associated with the step-down fixes), and he did not discuss go-around decision criteria. Further, although not specifically required, it would have been prudent for the captain to note the need for special caution in the UNZ VOR area (which he had described as a "black hole" in his approach briefing to another first officer about 1 month earlier).

The Safety Board further notes that, in this case, a thorough briefing was especially important because the accident captain and first officer were flying together for the first time, which is a situation that has been linked to flight crew-involved accidents.[191] According to recent human factors research, a good briefing is important to develop a "shared mental model" to ensure "that all crew members are solving the same problem and have the same understanding of priorities, urgency, cue significance, what to watch out for, who does what, and when to perform certain activities."[192] The Safety Board concludes that, by not fully briefing the instrument approach, the captain missed an opportunity to prepare himself, the first officer, and the flight engineer for the relatively complex localizer-only approach and failed to provide the first officer and flight engineer with adequate guidance about monitoring the approach; therefore, the captain's approach briefing was inadequate.

2.4.1.2 Expectation of a Visual Approach and Role of the Guam Airport Familiarization Video

The Safety Board notes that, when the captain flew to Guam about 1 month before the accident, he executed a routine ILS approach to runway 6L in good visibility, with a scattered cumulous buildup. Further, the most current ATIS information available to the accident flight crew indicated that visual conditions (scattered cloud decks and 7-mile visibility) existed at the airport. Korean Air's Guam airport familiarization video, which the captain and first officer had viewed in July 1997, noted that weather conditions in Guam allowed visual approaches most of the year and that, even though IMC is likely during the rainy season from June to November, "you [the pilot] will be guided from over Apra Harbor to the localizer. You will then perform a visual approach … ." Thus, the captain may have assumed that conditions for the flight 801 approach would be similar to those he experienced about 1 month earlier. The captain's anticipation of a visual approach probably became a strong expectation after the flight crew's early visual sighting of Guam. Although the captain would likely have recognized the possibility of flight through clouds as the airplane descended from its cruise altitude, he may have assumed that the visual approach slope indicator (VASI) system would be in sight after the flight was vectored onto final approach by the CERAP controller. The VASI system would have provided visual guidance for a constant angle of descent that safely cleared obstacles.

As previously discussed, the captain's landing briefing included references to his expectation of visual conditions at the airport as well as an abbreviated and inadequate briefing for the localizer-only approach. The Safety Board concludes that the captain's expectation of a visual approach was a factor in his incomplete briefing of the localizer approach. The Board is aware that it is a common practice among air carrier pilots to abbreviate the briefing for a backup instrument approach when a visual approach is expected. Although there may be little benefit to fully briefing a backup instrument approach in daylight conditions when no appreciable possibility of encountering IMC exists, the Safety Board concludes that, for flights conducted at night or when there is any possibility that IMC may be encountered, the failure to fully brief an available backup instrument approach compromises safety. Therefore, the Safety Board believes that the FAA should require principal operations inspectors (POI) assigned to U.S. air carriers to ensure that air carrier pilots conduct a full briefing for the instrument approach (if available) intended to back up a visual approach conducted at night or when IMC may be encountered.

The Safety Board notes that, although Guam was not a designated special airport requiring special training or familiarization by flight crews, Korean Air encouraged its flight crews to view the airport familiarization video. However, the Guam familiarization video gave only a generalized description of the topography of the island of Guam. Although the video mentioned some of the obstacles near the approach course, it did not specifically state that the UNZ VOR was located on a hill, the DME was not colocated with the localizer, or the final approach segment was over hilly or mountainous terrain.

Even though the airport familiarization video accurately identified some landmarks and advised pilots not to fly over a residential area and a Naval hospital (for noise abatement), the Safety Board also notes with concern that the video contained no discussion of factors that made operations into Guam challenging, such as the high terrain along the approach course or in the vicinity of the airport. Further, the presentation did not describe the complexity of the Guam nonprecision approaches, including the multiple step-down fixes, the use of two separate navigation facilities (the localizer and the VOR), and the countdown/count up DME procedure.

The Safety Board concludes that the Korean Air airport familiarization video for Guam, by emphasizing the visual aspects of the approach, fostered the expectation by company flight crews of a visual approach and, by not emphasizing the terrain hazards and offset DME factors, did not adequately prepare flight crews for the range of potential challenges associated with operations into Guam. Thus, the Safety Board believes that the KCAB should require Korean Air to revise its video presentation for Guam to emphasize that instrument approaches should also be expected and describe the complexity of such approaches and the significant terrain along the approach courses and in the vicinity of the airport.

The Safety Board addressed the issue of the classification of special airports and approaches to certain airports in connection with its investigation of the October 19, 1996, accident involving Delta Air Lines flight 554, an MD-88, at LaGuardia Airport in New York. On August 25, 1997, the Board issued Safety Recommendations A-97-92 through -94, asking the FAA to develop and publish "specific criteria and conditions" for the classification of special airports (including special runways and/or special approaches) and use these criteria to evaluate all airports and "update special airport publications." On November 13, 1997, the FAA responded that it was revising Advisory Circular (AC) 121.445, "Pilot-in-Command Qualifications for Special Area/Routes and Airports," and that the revision would address the issues discussed in the safety recommendations. On August 17, 1998, the Board classified Safety Recommendations A-97-92 through -94 "Open — Acceptable Response" pending completion of the AC. The Board recognizes that the FAA's eventual evaluation of Guam against the newly developed criteria might result in its classification as a special airport.

The Safety Board further recognizes that, because the captain flew into Guam and viewed the Guam airport familiarization video during July 1997, he would have been authorized to conduct the accident flight even if Guam had been classified as a special airport. Nonetheless, the Safety Board concludes that the challenges associated with operations to Guam International Airport support its immediate consideration as a special airport requiring special pilot qualifications. Therefore, the Safety Board believes that the FAA should consider designating Guam International Airport as a special airport requiring special pilot qualifications.

2.4.1.3 Possible Explanations for the Approach Conducted

2.4.1.3.1 Confusion About Status of Glideslope

Despite several indications that the flight crew was aware that the glideslope was inoperative, in the last 2 1/2 minutes of the flight (beginning shortly after the airplane was established on the approach), the CVR recorded a series of conflicting flight crew comments concerning the operational status of the glideslope. About 0139:55, the flight engineer asked, "is the glideslope working?" The captain responded, "yes, yes it's working." About 0139:58, an unidentified voice in the cockpit stated, "check the glideslope if working?" One second later, an unidentified voice in the cockpit stated, "why is it working?" About 0140:00, the first officer responded, "not useable." About 0140:22, an unidentified voice in the cockpit stated, "glideslope is incorrect," followed by the captain's statement, "since today's glideslope condition is not good, we need to maintain one thousand four hundred forty [feet]." However, about 0141:46, after the airplane crossed the GUQQY outer marker (1.6 DME from the VOR), the captain again stated, "isn't glideslope working?"

The Safety Board considered whether the flight crew might have misinterpreted some cockpit instrumentation indications as a valid glideslope capture signal. During the localizer approach into Guam, both pilots' HSIs would have appeared centered; the captain's would have captured the localizer, and the first officer's would have captured the VOR radial. With VOR/LOC selected, the localizer captured, and the pitch commands set to VERT SPEED (the most likely setting), the captain's FD command bars would have shown some vertical and horizontal movement, similar to an FD that was responding to a captured localizer and glideslope. However, the raw data glideslope needles on the attitude director indicator (ADI) and HSI would not have been affected by the VERT SPEED setting; therefore, the captain's ADI and HSI glideslope needles should have been covered by "off" flags.[193] Further, there would have been no glideslope capture annunciator on the GS bar of the FMA on top of the captain's and first officer's instrument panels.

The Safety Board also considered whether the flight crewmembers might have observed intermittent movement of the glideslope needles during the approach, thereby creating or adding to their confusion about the glideslope. An FAA navigation expert testified at the Safety Board's public hearing that spurious radio signals could cause a sporadic or intermittent glideslope indicator deviation in the absence of a valid glideslope signal. However, he stated that the glideslope off flag would still appear on the HSI and ADI glideslope needles and that, when the off flag appears, any movement of the glideslope needle should be considered unreliable. Postaccident testing by Korean Air and the KCAB confirmed that an airplane's glideslope receiver could be affected by spurious radio signals when no valid glideslope signal was being transmitted. The tests demonstrated that spurious signals could cause movement of the glideslope needle and that, when the receiver was subjected to a steady signal, retraction of the off flag was also possible. However, the Safety Board notes that these tests were conducted with an airplane on the ground and that the airplane's navigational receiver was subjected to extreme signal modulations transmitted very near the airplane's antenna. These conditions are not likely to be encountered by an airplane on an actual instrument approach.

The Safety Board also notes that the flight crew of a Boeing 727 reported glideslope anomalies on August 5, 1997, while executing the localizer-only approach to runway 6L at Guam.[194] (The purpose of the flight was to test a newly installed GPS.) However, the captain of the 727 stated that he thought the glideslope anomaly might have been caused by the GPS wiring installation. Further, the first officer stated that he and the captain "never thought twice" about the glideslope indications because they knew that the glideslope was inoperative. The Board's investigation into the 727's maintenance history indicated that, in the weeks after the test flight, several cockpit navigational displays, including the first officer's HSI and ADI, were repeatedly removed and replaced by maintenance personnel because of anomaly reports written up by flight crews. The maintenance documents indicated that the cockpit display problems were the result of integrating the new GPS with the existing cockpit displays.

Although it is possible that spurious radio signals caused some erratic movement of the glideslope needles on the accident captain's HSI and ADI, it is unlikely that the accident airplane's navigation receivers could have been subjected to a steady spurious signal of a duration that would have resulted in a continuous glideslope needle activation and flag retraction over a period of minutes and several miles of aircraft motion. Thus, the presence of the off flags over the glideslope needles at some times and the absence of FMA glideslope capture indicators on the captain's and first officer's instrument panels should have been sufficient to convince the flight 801 flight crew to disregard the glideslope indications. Even if the flight crewmembers did see a continuous glideslope needle activation and flag retraction, it would not have been prudent or reasonable for them to rely on a glideslope signal of any sort when the glideslope had been reported to be unusable. (Korean Air officials stated that flight crews were trained not to use navigational aids, including glideslopes, that were reported to be unreliable or unusable). Therefore, the Safety Board concludes that, although the captain apparently became confused about the glideslope's status, the flight crew had sufficient information to be aware that the glideslope was unusable for vertical guidance and should have ignored any glideslope indications while executing the nonprecision localizer-only approach.

The Safety Board notes that, when a glideslope signal is not generated by the transmitter (resulting in an open frequency channel), an airborne glideslope receiver will continue to seek a glideslope signal, although navigation receiver filters are designed to block most spurious radio signals. The postaccident testing conducted by Korean Air and the KCAB involved the glideslope receiver; however, the Safety Board concludes that navigation receivers, including glideslope receivers, may be susceptible to spurious radio signals. Therefore, the Safety Board believes that the FAA should disseminate information to pilots, through the Aeronautical Information Manual, about the possibility of momentary erroneous indications on cockpit displays when the primary signal generator for a ground-based navigational transmitter (for example, a glideslope, VOR, or nondirectional beacon [NDB] transmitter) is inoperative. Further, this information should reiterate to pilots that they should disregard any navigation indication, regardless of its apparent validity, if the particular transmitter was identified as unusable or inoperative.

2.4.1.3.2 Confusion About Location of DME

About 0140:37, when the airplane was at 2,400 feet msl and descending at 1,000 feet per minute, the captain stated, "since today's glideslope condition is not good, we need to maintain one thousand fourteen hundred forty [feet]. please set it." This statement suggests that the captain was attempting to comply with the restrictions of the localizer-only approach and believed that he had passed the GUQQY step-down fix. However, the CVR recorded no discussion between the captain and the first officer about DME values or their position in relation to the next step-down fix, the VOR, or the airport.

The Safety Board considered whether the flight crew might have confused the configuration of the runway 6L localizer approach with one in which the DME is located on the airport. A review of the flight crew's training records showed that the nonprecision approaches incorporating DME provided to the flight crew during training and check rides had the DME located on the airport. A countdown/count up DME procedure, which is rarely encountered on a localizer procedure, was not included in any of the Korean Air simulator training scenarios. If the flight crewmembers had the misconception that the DME information referred to the distance from the airport, they might have believed that the airplane was much closer to the airport than it actually was (the DME was located 3.3 nm southwest of the airport) and that the airplane was well above the minimum altitudes for the intermediate step-down fixes and thus ready to descend directly to the MDA. If the captain had this misconception, it could explain why he flew the airplane and commanded altitude selections as though he believed he was at or above the altitude constraint for each navigational fix along the approach. If the other flight crewmembers shared this misconception, it could explain why they failed to challenge the captain's premature descents below 2,000 and 1,440 feet.

However, this scenario suggests strongly that the captain was not noting the definitions of the navigational fixes on the approach chart, which were clearly defined as DME values.[195] Thus, the Safety Board concludes that the captain may have mistakenly believed that the airplane was closer to the airport than its actual position; however, if the captain conducted the flight's descent on this basis, he did so in disregard of the DME fix definitions shown on the approach chart.

2.4.1.4 Summary of Captain's Performance on the Approach

As the approach progressed without encountering the visual conditions the captain had anticipated, the captain likely experienced increased stress because of his inadequate preparation for the nonprecision approach, which made the approach increasingly challenging.[196] CVR and FDR data indicated that, shortly after the captain appeared to become preoccupied with the status of the glideslope, he allowed the airplane to descend prematurely below the required intermediate altitudes of the approach. Thus, the captain may have failed to track the airplane's position on the approach because he believed that he would regain visual conditions, the airplane was receiving a valid glideslope signal, and/or the airplane was closer to the airport than its actual position.

Regardless of the reason for failing to track the airplane's position, the captain conducted the approach without properly cross-referencing the positional fixes defined by the VOR and DME with the airplane's altitude. Therefore, the Safety Board concludes that, as a result of his confusion and preoccupation with the status of the glideslope, failure to properly cross-check the airplane's position and altitude with the information on the approach chart, and continuing expectation of a visual approach, the captain lost awareness of flight 801's position on the ILS localizer-only approach to runway 6L at Guam International Airport and improperly descended below the intermediate approach altitudes of 2,000 and 1,440 feet, which was causal to the accident.

2.4.2 Flight Crew Monitoring of the Approach

CVR evidence indicated that the flight crew seemed confused about, and did not react to, a series of audible ground proximity warning system (GPWS) alerts during the final approach. The first audible GPWS callout occurred about 0141:42, with the "one thousand [feet]" altitude call. A second GPWS callout of "five hundred [feet]" occurred about 0142:00 (when the airplane was descending through about 1,200 feet msl), to which the flight engineer responded in astonishment, "eh?" However, FDR data indicated that no change in the airplane's descent profile followed, and the CVR indicated that the flight engineer continued to complete the landing checklist. Similarly, no flight crew discussion followed the GPWS callout of "minimums" about 0142:14, and the first officer dismissed a GPWS "sink rate" alert 3 seconds later by stating "sink rate okay." About 0142:19, the flight engineer called "two hundred [feet]," followed immediately by the first officer saying "let's make a missed approach." The flight engineer immediately responded "not in sight," followed by the first officer repeating "not in sight missed approach." According to the CVR, a rapid succession of GPWS altitude callouts down to 20 feet followed, as the flight crew attempted to execute the missed approach.

The GPWS minimums callout occurred about 12 seconds before impact, when the airplane was descending through about 840 feet msl. The first officer's first statement suggesting the execution of a missed approach occurred about 6 seconds before impact. The captain initiated a missed approach and thrust began increasing about 4 seconds before impact. However, no significant nose-up control column inputs were made until just before initial impact. Analysis of FDR data indicated that, if a missed approach had been initiated 12 seconds before impact (at the GPWS minimums callout), it is likely that the airplane would have successfully cleared terrain by about 450 feet. Analysis of the FDR data also indicated that, if an aggressive missed approach had been initiated 6 seconds before impact (when the first officer made the first missed approach challenge), it is possible that the airplane might have cleared the terrain.

The Safety Board notes that the flight crew would have been gauging the airplane's height above the MDA by referring to the airplane's barometric altimeter (which displays altitude above sea level) and not the radio altimeter (which senses altitude above ground level and upon which the GPWS minimums callout was based) and that the MDA of 560 feet msl was never reached. Nevertheless, the GPWS callouts were a salient cue that should have caused the flight crew to question the airplane's position and the captain to act conservatively and choose to execute a missed approach. The Safety Board concludes that the first officer and flight engineer noted the GPWS callouts and the first officer properly called for a missed approach, but the captain's failure to react properly to the GPWS minimums callout and the direct challenge from the first officer precluded action that might have prevented the accident.

Although the first officer properly called for a missed approach 6 seconds before impact, he failed to challenge the errors made by the captain (as required by Korean Air procedures)[197] earlier in the approach, when the captain would have had more time to respond. Significantly, the first officer did not challenge the captain's premature descents below 2,000 and 1,440 feet.

The Safety Board was unable to identify whether the absence of challenges earlier in the approach stemmed from the first officer's and the flight engineer's inadequate preparation during the approach briefing to actively monitor the captain's performance on the localizer approach, their failure to identify the errors made by the captain (including the possibility that they shared the same misconceptions as the captain about the glideslope status/FD mode or the airplane's proximity to the airport), and/or their unwillingness to confront the captain about errors that they did perceive.

The Safety Board notes that the captain's failure to brief the localizer approach to back up the expected visual approach could have adversely affected the flight crew's preparation for monitoring the approach. If the captain had briefed the details of the approach, including the various navigational fix definitions and associated altitude constraints, he would have enhanced the flight crew's ability to monitor the approach and challenge any errors he made.

Even if the first officer was attempting to monitor the approach, his ability to identify errors made by the captain would have been impaired by the requirement that he tune his navigation receiver to the UNZ VOR, thus forcing him to look across the cockpit to the captain's instruments to monitor the glideslope/FD status, any indications of glideslope capture on the captain's ADI and HSI, and the airplane's lateral position on the localizer. However, the first officer would have had information on his own HSI and radio magnetic indicator about the airplane's position relative to the VOR (the step-down fix for the descent to 560 feet) and the DME readings that defined the remaining fixes of the approach.

The first officer's ability to monitor the captain was also possibly hindered by the likelihood that he was using a different instrument chart than the captain for the localizer approach. The Safety Board found an out-of-date chart for this approach (dated January 19, 1996) in the cockpit. On the basis of the captain's comments on the CVR, it appears that the captain was using the correct chart (dated August 2, 1996), which included different definitions and names of DME fixes and different crossing altitudes than the out-of-date chart. Thus, if the first officer was using the out-of-date chart, he would have been hindered in monitoring the captain's compliance with the altitude constraints at the fixes.

Although the precise reason(s) for the lack of monitoring by the flight crew could not be determined, the Safety Board concludes that the first officer and flight engineer failed to properly monitor and/or challenge the captain's performance, which was causal to the accident.

Problems associated with subordinate officers challenging a captain are well known. For example, in its study of flight crew-involved major air carrier accidents in the United States,[198] the Safety Board found that more than 80 percent of the accidents studied occurred when the captain was the flying pilot and the first officer was the nonflying pilot (responsible for monitoring). Only 20 percent of the accidents occurred when the first officer was flying and the captain was monitoring. This finding is consistent with testimony at the Safety Board's public hearing, indicating that CFIT accidents are more likely to occur (on a worldwide basis) when the captain is the flying pilot. (See section 2.8 for a discussion of CFIT accidents and prevention strategies, including monitored approaches.) The Board's study found that the failure of first officers to challenge errors (especially tactical decision errors) made by a flying captain was a frequent factor in accidents involving such errors. In addition, the study noted that, while monitoring and challenging a captain's tactical decision error, "a first officer may have difficulty both in deciding that the captain has made a faulty decision, and in choosing the correct time to question the decision." The study concluded that a first officer "may be concerned that a challenge to a decision may be perceived as a direct challenge to the captain's authority."

The Safety Board is concerned that the use of the nonflying pilot in a passive role, while the flying pilot is responsible for the approach procedure, programming the autopilot/FD controls, and monitoring the aircraft flightpath, places an inordinately high work load on the flying pilot and undertasks the nonflying pilot. The Board is also concerned that, when the nonflying pilot has a passive role in the approach, the flying pilot may erroneously consider the lack of input from the nonflying pilot as confirmation that approach procedures are being properly performed. The Board is aware that some international air carriers use the nonflying pilot in a more interactive role during the performance of a nonprecision approach, in which that pilot leads or prompts the flying pilot through the approach procedure by stating the next procedural change, including course, heading, altitude, time, visual contact, or MAP. The Board is also aware that some air carriers employ a "monitored approach" method, with the first officer as the flying pilot and the captain as the monitoring, nonflying pilot until just before landing.

The Safety Board notes that the monitored approach method provides for more effective monitoring by the nonflying pilot because captains are more likely to be comfortable offering corrections or challenges to first officers than the reverse situation. Thus, the Safety Board concludes that monitored approaches decrease the workload of the flying pilot and increase flight crew interaction, especially when experienced captains monitor and prompt first officers during the execution of approaches. However, the Board also notes that, when there are differences in aircraft handling skills between captains and first officers and the approach is not flown using the autopilot, a monitored approach with the captain as the nonflying pilot may not always be appropriate. Therefore, the Safety Board believes that the FAA should conduct or sponsor research to determine the most effective use of the monitored approach method and the maximum degree to which it can be safely used and then require air carriers to modify their procedures accordingly.

2.4.3 Flight Crew Fatigue Factors

Fatigue can be a factor in flight operations.[199] The Safety Board examined several fatigue-related factors, including time of day, recent sleeping patterns, and the number of hours since awakening, to determine whether fatigue was a factor in the accident captain's performance. The Board was unable to obtain information on the recent sleeping patterns of the first officer and flight engineer.

The accident occurred after midnight (about 0042) in the flight crew's home time zone (which is 1 hour behind Guam local time). Research has found that this time of day is often associated with degraded alertness and performance and a higher probability of errors and accidents.[200] The arrival time was also several hours after the captain's normal bedtime (2200 to 2300 Seoul local time) and a time at which his body would have been primed for sleep. CVR evidence indicated that the captain was tired. At the beginning of the approach, the captain made unsolicited comments related to fatigue, stating "eh … really … sleepy." In its investigation of the 1993 American International Airways accident at Guantanamo Bay, Cuba, the Safety Board noted that individuals often tend to underestimate their own level of fatigue.[201] Thus, the captain's comment could have reflected a significant performance degradation. Neither the first officer nor the flight engineer made similar comments.

According to his family, the captain slept his normal sleep routine in the days before the accident and had an opportunity to receive adequate rest. He also took a nap from 1100 to 1340 (Seoul local time) on August 5 and would therefore have been awake for 11 hours at the time of the accident. The Safety Board has found this time since awakening to be associated with greater errors.[202] For example, in its investigation of the 1993 accident in Pine Bluff, Arkansas, the Board determined that the captain and first officer had both been awake for 11 hours.[203]

Further, the sleep history provided by the captain's family does not address the quality of sleep he received. For example, the time of the captain's reported nap corresponds to a typical physiological period of wakefulness when napping is difficult[204] and of limited efficiency at reducing sleep debt.[205] If the captain actually napped at this time, it suggests that he may have had unusual sleep needs that were not indicated by the number of hours in his reported sleep history.[206]

Fatigue degrades all aspects of performance and alertness, and deficiencies associated with fatigue were displayed in many aspects of the captain's behavior. The captain's preoccupation and confusion with the status of the glideslope to the exclusion of other critical information, his incomplete briefing, and his failure to react to the GPWS alerts are typical of fatigue effects that were found to be present in the Guantanamo Bay and Pine Bluff accidents.

On the basis of the time of day, statements recorded on the CVR, and sleep and fatigue research, the Safety Board concludes that the captain was fatigued, which degraded his performance and contributed to his failure to properly execute the approach.

2.5 Pilot Training

The Safety Board examined Korean Air's Boeing 747 pilot training and proficiency checking program to determine what effect, if any, it may have had on the performance of the flight crew of flight 801. In training its pilots to fly the 747-200 and -300 series airplanes, Korean Air conducted 10 4-hour simulator sessions in which pilots were taught various maneuvers, emergencies, and scenarios, followed by a proficiency check in which pilot performance of certain maneuvers was assessed. The profile for each simulator training session outlined the specific airport, runway, weather, and airplane malfunction to be expected and whether the flight would result in a landing or missed approach. The training curriculum was not varied. Korean Air's Director of Academic Training testified at the Safety Board's public hearing that, at the time of the accident, the company's practice was to follow simulator scenarios exactly as outlined in the training curriculum and that instructors were not permitted to vary the scenarios. The director also indicated that the proficiency checks used the same approaches that had been practiced in the previous simulator training sessions.

Further, the only nonprecision approach practiced throughout the simulator sessions that used DME information was the VOR/DME approach to runway 32 at Seoul's Kimpo Airport. However, the DME at that airport is located on the field, unlike at Guam. No scenario was presented in which pilots were required to count down to and fly past the DME and then count up to the MAP, which was required for the Guam approach.[207] Further, according to the airline's training syllabus, the VOR/DME approach to runway 32 at Kimpo was the only nonprecision approach that Korean Air flight crews were required to perform on their check ride.

The Safety Board notes that proper training in the execution of nonprecision approaches is essential to safe operations. The complexity of such approaches and the absence of precise vertical guidance create more demands on pilot skills and cognitive performance than precision approaches. An expert on CFIT accidents testified the following at the Board's public hearing:

> Nonprecision approaches generally are much more complex than precision approaches. For many pilots, they are less familiar. They are more error-prone. They require [a] more comprehensive briefing. They need particularly careful and accurate monitoring, and it is possible for complex step-down procedures for steps to be missed or to be taken out of step. In other words, to get one step ahead of the airplane could be fatal. Such approaches also need much more carefully managed airplane crew and checklist management, and it is a characteristic of many CFIT accidents that they occur when the crew is preoccupied or distracted by other tasks.

The Safety Board notes that the Air Line Pilots Association (ALPA), in its submission regarding this accident, estimated that air transport pilots typically conduct one to three nonprecision approaches a year and practice these approaches "just as infrequently" in the simulator. In its investigation of the November 12, 1995, accident involving American Airlines flight 1572, an MD-83 that crashed in East Granby, Connecticut, while on final approach to Bradley International Airport in Windsor Locks, Connecticut,[208] the Board found that even relatively minor errors in the monitoring of the execution of a nonprecision approach can lead to an accident.[209]

The Safety Board is concerned that the repeated presentation of a single nonprecision approach scenario throughout simulator training (to the exclusion of all other kinds of nonprecision approaches) provides insufficient training in nonprecision approaches. Specifically, the repetition limits pilots' opportunity to understand and practice the flying techniques necessary to perform the different kinds of nonprecision approaches and limits their ability to successfully apply these techniques to novel situations or unusual approach configurations encountered in line operations, such as the localizer approach at Guam. Further, Korean Air's reliance on the same approach for both training and checking resulted in an inadequate evaluation of a flight crew's ability to execute the varied nonprecision approaches that might be encountered in line operations.[210] Therefore, the Safety Board concludes that Korean Air's training in the execution of nonprecision approaches was ineffective, which contributed to the deficient performance of the flight crew.

In addition, on the basis of the history of similar accidents involving U.S. air carriers, the Safety Board concludes that U.S. air carrier pilots would benefit from additional training and practice in nonprecision approaches during line operations (in daytime visual conditions in which such a practice would not add a risk factor). Therefore, the Safety Board believes that the FAA should issue guidance to air carriers to ensure that pilots periodically perform nonprecision approaches during line operations in daytime visual conditions in which such practice would not add a risk factor.

2.6 Air Traffic Control Factors

2.6.1 Controller Performance

Safety Board investigators evaluated the performance of the CERAP and Agana tower controllers to determine whether their performance played a role in the circumstances of the accident. FAA Order 7110.65, "Air Traffic Control," prescribes the ATC procedures that controllers are required to follow. The investigation revealed three deviations from those procedures on the part of the CERAP controller.

The CERAP controller failed to provide the flight crew with a position advisory relative to a fix on the final approach course when he cleared flight 801 for the approach. If such a position advisory had been given, as required by paragraph 5-9-4, the pilots might have been prompted to cross-check their radar position with the cockpit DME and other navigational aid indications, thereby improving their situational awareness. In addition, the CERAP controller did not inform the flight crew or the tower controller that he had observed a rain shower (described by the CERAP controller as a "cell" during a postaccident interview with Safety Board investigators) on the final approach path, as required by paragraph 2-6-4. Although the pilots should have been aware of the weather situation because they were using on-board weather radar, their decision-making might have been aided if the CERAP controller had provided his weather observations.

The CERAP controller also failed to monitor the flight after the frequency change to the tower controller.[211] As a result, the CERAP controller did not immediately recognize that the airplane was overdue. (Paragraph 10-3-1 states that a controller who has any reason to believe that an aircraft is overdue should immediately take appropriate action.) If the CERAP controller had been properly monitoring the flight on one or both of the radar displays he had available to him (the en route display and/or the terminal display), he might have observed flight 801 disappear on final approach. Also, the controller might have noticed the approach path warning (low-altitude MSAW alert) that was generated on the en route radar display,[212] which began about 6 seconds before impact and continued until at least 23 seconds afterward. These actions would have resulted in an earlier notification of the accident to emergency rescue personnel and possibly an earlier emergency response. (See section 2.7 for a discussion of the emergency response.)

Further, if the CERAP controller had been monitoring the flight on the terminal radar display, which was located to his immediate right and would have been clearly visible to him,[213] he might have seen the airplane descend prematurely toward high terrain and have been able to alert the flight crew and prevent the accident. This radar display would have shown the flight descending through 2,000 feet msl while almost 7 miles from the airport and outside of the outer marker. The radar display would have also shown the airplane crossing the outer marker almost 800 feet lower than the established crossing altitude of 2,000 feet.[214]

Although the CERAP controller told Safety Board investigators that he did not continue to monitor the flight because he was engaged in other duties about the time of the accident, the ATC transcripts indicated no activity during that time. The transcripts indicated that the controller instructed the flight crew, about 0140:42, to contact the Agana tower. The controller then made a radio transmission to another aircraft about 0140:54. From about 0141:14 to 0141:30, the controller had a conversation with another controller at a different center, and about 0142:05, he acknowledged a transmission from another aircraft. However, the transcripts indicated no further activity until 0143:49, when the CERAP controller called the Agana tower with a flight plan. Thus, the ATC transcripts indicated no activity during the time period beginning 21 seconds before and continuing until 1 minute 23 seconds after the flight 801 crash (which occurred about 0142:26). Therefore, the CERAP controller should have been able to monitor the flight during this time. If the controller had done so, he would have had an opportunity to warn the flight crew of the flight's premature descent and possibly prevent the accident.

The Safety Board concludes that the CERAP controller's performance was substandard in that he failed to provide the flight crew with a position advisory when he cleared the flight for the approach, inform the flight crew or the Agana tower controller that he had observed a rain shower on the final approach path, and monitor the flight after the frequency change to the tower controller. It could not be determined whether the absence of the CERAP controller's procedural errors, singularly or in any combination, would have prevented the accident or reduced its severity. However, the Safety Board concludes that strict adherence to ATC procedures by the CERAP controller may have prevented the accident or reduced its severity. Therefore, the Safety Board believes that the FAA should develop a mandatory briefing item for all air traffic controllers and ATC managers, describing the circumstances surrounding the performance of the CERAP controller in this accident to reinforce the importance of following ATC procedures.

2.6.2 Intentional Inhibition of the Minimum Safe Altitude Warning System at Guam

Since February 1995, the Guam ARTS IIA MSAW system[215] had been intentionally inhibited by the FAA from providing low-altitude alerts inside a 54-nm ring around the ASR-8 radar antenna. The system was inhibited because it had been generating what air traffic controllers believed to be numerous false alerts, or "nuisance warnings." Thus, at the time of the accident, the MSAW system was only available (uninhibited) in a 1-mile-wide band around the ASR-8 radar site, between 54 and 55 nm. Korean Air flight 801 crashed approximately 3 nm southwest of Guam International Airport in an area of rising terrain that would have been covered by the MSAW system if it had not been inhibited.

FAA technical staff and Safety Board investigators conducted a postaccident simulation using the original parameters intended for the system. The simulation results indicated that, if the MSAW system had not been inhibited inside the 54-nm radius, both a visual and aural low-altitude alert would have been generated on the ARTS IIA monitors in the CERAP facility about 0141:22, as the airplane was descending through 1,700 feet msl. Accordingly, the Safety Board concludes that, if the ARTS IIA MSAW system had been operating as initially intended, a visual and aural warning would have activated about 64 seconds before flight 801 impacted terrain, and this warning would have likely alerted the CERAP controller that the airplane was descending below the minimum safe altitude for that portion of the approach.

Flight 801 was under the control of the Agana tower controller at the time that the low-altitude MSAW alert would have been issued by the ARTS II system in the CERAP facility. The Agana tower was not equipped with a functioning terminal radar display. Therefore, for the crew of flight 801 to have received a low-altitude advisory, the CERAP controller (who was still responsible for monitoring the airplane after he initiated a frequency change to the tower controller) would have had to relay the alert to the tower controller, who would then have had to convey the alert to the flight crew. Given the prevalence of CFIT accidents, controllers would be expected to vigilantly monitor the system and provide timely notification to either another controller or a flight crew when an MSAW alert indicates the existence of an unsafe situation. The Safety Board concludes that 64 seconds would have been sufficient time for the CERAP controller to notify the Agana tower controller of the low-altitude alert, the tower controller to convey the alert to the crew of flight 801, and the crew to take appropriate action to avoid the accident.

Because of its periodic evaluations of air traffic facilities, FAA quality assurance staff knew as early as July 1995 that the Guam ARTS IIA MSAW system had been inhibited. The inhibition was cited in a 1995 FAA facility evaluation report but was only classified as an "informational" item. The FAA conducted no followup activities after the 1995 evaluation to determine whether corrective action had been taken to restore the MSAW system to the full service for which it was designed. In April 1997, the FAA conducted a second evaluation of the Guam facility, but the FAA's report on this evaluation did not even note that the ARTS IIA MSAW system was inhibited. Thus, the FAA missed two opportunities not only to recognize that the MSAW system was inhibited to the extent that it was rendered almost completely useless but also to take corrective action. An appropriate corrective action could have prevented this accident. Therefore, the Safety Board concludes that the FAA's quality assurance for the MSAW system was inadequate, and the agency's intentional inhibition of that system contributed to the flight 801 accident.

As previously noted, in this accident there would have been sufficient time (64 seconds), if the MSAW system had generated an alert in the CERAP facility, for the CERAP controller to have relayed the information to the tower controller. However, under different circumstances, an aircraft descending below the minimum safe altitude may not generate an MSAW alert as far in advance, so controllers may have significantly less time to react. In those cases, it would make a critical difference if the MSAW alert were provided directly to the airport tower.

The Safety Board has long been concerned about the issue of aural MSAW alerts in towers. As part of its investigation into the January 1995 Beechcraft A36 accident, the Safety Board found that the FAA did not have a policy regarding the installation of an aural MSAW alert at low-density ATC towers equipped with D-BRITE radar displays. As a result, the Safety Board issued Safety Recommendation A-95-120 on November 30, 1995. Safety Recommendation A-95-120 asked the FAA to develop a policy that would require the installation of aural MSAW equipment in those visual flight rules (VFR) terminal facilities that receive radar information from a host radar control facility and would otherwise receive only a visual MSAW alert.[216]

In June 1996, the FAA stated that it was feasible to install the aural MSAW alert in 112 VFR towers. In July 1997, the FAA stated that 69 of 112 ATC facilities did not have remote displays with aural alarms and that aural alarms at these facilities would be installed by February 1998. In May 1998, the FAA stated that the aural alarms at these 69 remote sites would be operational by the end of that month. However, in March 1998, at the Safety Board's public hearing, the FAA's Deputy Program Director for Air Traffic Operations indicated that the new projected completion date for the installation of aural alarms in VFR towers was April 2000. In October 1998, the Safety Board expressed its concern to the FAA that VFR tower controllers who have visual representation from a distant host radar may not receive an aural alert when aircraft under their control, or with whom they are in radio communication, descend below the minimum safe altitude. The Board asked the FAA to ensure that all VFR tower controllers with visual representation from a host radar would in fact receive such warning. Pending further information from the FAA, Safety Recommendation A-95-120 was classified "Open — Acceptable Response."

On September 29, 1999, a representative from the FAA stated that the agency's management had indicated that the Agana tower was currently receiving aural MSAW alerts. At an October 7, 1999, briefing attended by the FAA Administrator, the Safety Board Chairman, and staff from both agencies, the FAA indicated that 69 MSAW aural alarms had been delivered and that 51 alarms were to be delivered. The FAA expected that the acquisition of these 51 alarms would be completed by October 2000 and that their installation in VFR towers would be completed by April 2001.

On October 12, 1999, the FAA Program Director for Serco Aviation Services told Safety Board staff that the Agana tower has the capability to receive an aural MSAW alert but that, unless the Guam CERAP transfers responsibility for the aircraft's data block, the tower will not receive the warning. The official added that the CERAP does not currently transfer responsibility for the aircraft's data block to the Agana tower; therefore, the tower does not receive an aural MSAW alert.

On October 14, 1999, the FAA Program Director for Air Traffic Operations confirmed that Agana tower was not receiving aural MSAW alerts. In an October 15, 1999, facsimile, the program director indicated that the tower "has the software and hardware capability in place to receive aural alarms." The director further stated that the FAA had issued a policy "to ensure that the facility that is in direct radio communications with the aircraft receives the aural alarm" and that the policy would become effective by November 15, 1999. In a followup telephone conversation with the Safety Board's Director of the Office of Aviation Safety, the program director indicated that a national policy would be issued to ensure that procedures similar to those being implemented at Guam are followed at other VFR towers.

On October 25, 1999, the FAA indicated that the MSAW aural alarms for the ARTS IIA system at Guam were reconfigured on October 24, 1999. The FAA stated that, in the event of a low-altitude alert for an aircraft operating in the vicinity of Guam International Airport, aural alarms will be simultaneously generated at the CERAP and the Agana tower, along with visual low-altitude alerts on the radar displays at both facilities.

On November 2, 1999, the Safety Board received a copy of draft FAA Notice N7210.485, "Minimum Safe Altitude Warning for Remote Tower Displays." According to the notice, facility managers at ATC towers that have aural alarms for MSAW are to ensure that "the operational support facility has adapted the software functionality to ensure the aural alarms operate in the ATCT [air traffic control tower]" and that "aural alarms are received in the ATCT upon transfer of communications." The FAA indicated that the effective date for this notice would be February 1, 2000.

The Safety Board is concerned about the delay in the implementation of Safety Recommendation A-95-120.[217] In addition, the Safety Board is especially concerned that the FAA, until it received queries from the Board, was apparently not aware of, or not addressing, procedural barriers that prevented the installed equipment from being used as intended. However, on the basis of the FAA's apparent continued intention to fully implement this recommendation, it remains classified "Open — Acceptable Response."

2.7 Emergency Response

Although a fire station was located about 1 mile from the accident site, the first emergency response equipment (dispatched from a different fire station about 3 1/2 miles from the accident site) did not arrive on scene until approximately 52 minutes after the accident. Safety Board investigators attempted to determine the reason(s) for the slow emergency response and the extent to which it could have been reduced or avoided.

Because of the air traffic controllers' delayed discovery of the accident, ramp control personnel, who were responsible for emergency notifications, were not aware of the accident until 0158, about 16 minutes after the crash occurred. As discussed in section 2.6.1, if the CERAP controller had been monitoring the flight more closely, this delay might have been eliminated or reduced.

After being notified of the accident by Guam airport ramp control, the Guam Fire Department (GFD) communications center dispatched GFD Engine No. 7, which was stationed about 3 1/2 miles from the crash site, at 0207. However, Engine No. 7's departure from the station was delayed by 12 minutes because its brake system needed to be recharged with air. Engine No. 7 departed the station at 0219, and its en route response time was 15 minutes. Engine No. 7 was the first emergency response vehicle to arrive at the VOR access road (at 0234, 52 minutes after the accident).

The nearest fire station to the accident site was the U.S. Navy Federal Fire Department (located about 1 mile from the accident site). According to Federal dispatch facility logs, that station was not notified of the accident until 0234. The station's Engine No. 5 was then immediately dispatched and arrived at the accident scene at 0239 (a response time of 5 minutes). The Chief of Staff for the Commander, U.S. Naval Forces, Marianas, notified Navy "first responders" to stand by after she learned of the accident at 0216. However, the Navy had not yet received a request for specific Federal firefighting and medical resources; therefore, it would have been inappropriate for the Chief of Staff to have dispatched these resources.

The emergency response was further delayed because the VOR access road-a partially paved, single-lane road that was the only ground access to the accident site-was blocked by a section of severed pipe[218] when emergency responders arrived. Emergency responders had to walk to the crash site through steep, muddy terrain and dense vegetation until 0334, when a truck-mounted winch removed the pipe. Fire and rescue personnel stated that only small, isolated fires remained when they were finally able to reach the accident scene with firefighting equipment.

A U.S. Navy emergency medical technician assigned to the Naval Regional Medical Center reached the accident site on foot between 0245 and 0300. He stated that emergency responders established two triage areas to treat survivors. He added that transport of the survivors to hospitals was delayed because of the terrain and limited access to the crash site and the necessity to stabilize patients in triage. The first survivors were transported to hospitals between about 0300 and 0330. Rescue personnel testified at the Safety Board's public hearing that the pace of evacuations increased after the pipe blocking the access road was removed and a landing area for helicopters was set up near the VOR.

The Safety Board is concerned that the first emergency response equipment did not arrive at the accident scene until about 52 minutes after the accident. Although the harsh terrain and the broken pipeline could not have been controlled, the delay caused by air traffic controllers' initial unawareness of the accident, the need to recharge the brake system on the GFD Engine No. 7, and the lack of timely notification to the Federal Fire Department could have been avoided. Thus, the Safety Board concludes that a substantial portion of the delayed emergency response was caused by preventable factors. The autopsy reports indicated that at least one seriously injured passenger was treated at the accident site. Although the autopsy report for this passenger did not identify a single cause of death (her remains showed evidence of multiple internal injuries but no burns or soot in the airways), the report indicated that she was alive when medical personnel arrived, was treated aggressively, and might have survived if earlier medical intervention and evacuation had occurred. Therefore, the Safety Board concludes that the delayed emergency response hampered the timely evacuation of injured persons, and at least one passenger who survived the initial impact and fire might not have died if emergency medical responders had reached the accident site sooner.

According to public hearing testimony by Guam's Civil Defense Director, at the time of the accident, Guam emergency response authorities had a memorandum of understanding (MOU) with the U.S. Air Force for emergency response but did not have agreements with the U.S. Navy or U.S. Coast Guard. The director further stated that, before the accident, a joint disaster drill had been conducted at the airport, but no drills had been conducted for off-airport crash emergencies. At the public hearing, the Guam Civil Defense Director and other Guam officials stated that a committee, including representatives from Guam, the U.S. Navy, the U.S. Coast Guard, and the U.S. Air Force, had been formed to develop an MOU; an off-airport aircraft accident drill was planned for September 1998; and new radios had been purchased to allow interagency communication and coordination during emergency responses. However, Guam Civil Defense officials told the Safety Board in June 1999 that no MOU had been signed and that a draft of standard operating procedures for joint emergency response was being circulated to agencies for review. Further, Guam Civil Defense officials stated that the planned September 1998 off-airport aircraft accident drill did not take place and that such an exercise was still in the planning stage.

Although it is pleased with the purchase of new emergency radios, the Safety Board concludes that improved formal coordination among Guam's emergency response agencies has not been implemented, and off-airport drills to identify and correct deficiencies in disaster response planning before an accident occurs have still not been conducted in the more than 2 years since the flight 801 accident. Thus, the Safety Board also concludes that actions taken by Guam's emergency response agencies after the accident have been inadequate because they failed to ensure that emergency notifications and responses would be timely and coordinated. Therefore, the Safety Board believes that the Governor of the Territory of Guam should form, within 90 days, a task force comprising representatives from all emergency response agencies on the island, including the appropriate departments within the government of Guam, FAA, Guam International Airport Authority, U.S. Navy, U.S. Air Force, U.S. Coast Guard, Federal Emergency Management Agency, and all other affected agencies, to define and coordinate emergency notification and response procedures to ensure that timely emergency notifications are made to all local and Federal agencies according to need, location, and response time capability. Further, the Safety Board believes that the Governor of the Territory of Guam should require periodic and regularly scheduled interagency disaster response exercises, including an off-airport aircraft accident scenario, in addition to those response drills already required at Guam International Airport in accordance with 14 CFR Section 139.325.

2.8 Controlled Flight Into Terrain

According to Flight Safety Foundation (FSF) accident data, CFIT accidents have killed more passengers and crewmembers than any other type of air carrier accident, and approach and landing accidents accounted for 70 percent of CFIT accidents, with most accident airplanes "in line with the runway" at impact. CFIT accident data also indicated that nonprecision approaches presented a greater risk than precision approaches and that many CFIT accidents involved failed step-down approaches, with flight profiles similar to that of flight 801's approach to Guam. As noted in section 2.5, nonprecision approaches are practiced infrequently by air carrier pilots and generally require more extensive briefings and careful monitoring than a typical instrument approach.

The FSF CFIT task force also identified several common factors found in CFIT accidents, including night conditions, limited visibility, terrain not seen until just before impact, a stabilized descent path approximating a 3° slope, loss of horizontal and/or vertical situational awareness, unfamiliarity with terrain and obstructions, uncertainty about altitudes and/or distance from the airport, navigational equipment improperly set, or information misinterpreted. The Safety Board notes that many of these factors were present in this accident.[219]

On October 16, 1996, the Safety Board issued Safety Recommendation A-96-95, asking the FAA to develop a CFIT program that includes realistic simulator exercises comparable to the successful windshear and rejected takeoff training programs and make training in such programs mandatory for all pilots operating under 14 CFR Part 121. On February 25, 1997, the FAA issued a change to AC 120-51B, "Crew Resource Management," recommending that crew resource management (CRM) training in line-oriented flight training or special purpose operational training modules contain a CFIT scenario. However, the FAA did not require this CFIT training, as urged by the Safety Board. Pending further correspondence from the FAA, Safety Recommendation A-96-95 was classified "Open — Acceptable Response" on November 13, 1997.

A CFIT Education and Training Aid, which was developed under the auspices of the FSF and made available to air carriers in 1997, provides an overall summary of CFIT "traps," outlines causal factors of CFIT accidents, and provides training guidance for specific escape maneuvers. The education and training aid focuses on altimeter errors, procedural errors, misuse of automation, terrain avoidance, and aggressive escape maneuvers. The training materials include a video and a CFIT checklist designed to evaluate mission-specific CFIT risk factors, such as nonprecision approaches, airports near mountainous terrain, duty time, and weather factors. Thus, because CFIT is one of the leading categories of air carrier accidents and this type of accident is likely to increase as worldwide air traffic levels increase, the Safety Board concludes that CFIT accident awareness and avoidance training is an important accident reduction strategy and should be mandatory for all pilots operating under 14 CFR Part 121.

The Safety Board is disappointed that the FAA has not yet mandated CFIT training, despite its demonstrated value to air carrier flight crews and in the reduction of CFIT accidents. On August 11, 1999, the FAA stated that it had initiated a notice of proposed rulemaking (NPRM) to mandate CFIT training. The FAA indicated that the NPRM would be published in December 2000. Because of the FAA's planned rulemaking, Safety Recommendation A-96-95 remains classified "Open — Acceptable Response." However, the Safety Board notes with concern that the FAA's expected publishing date for the NPRM (December 2000) would occur more than 4 years after the issuance of the recommendation. Experience has shown that implementation of a final rule could take several additional years. In light of the fact that the CFIT training program is already available to the industry, this delay appears unnecessary and unreasonable. Therefore, the Safety Board urges the FAA to expedite this rulemaking.

2.8.1 Constant Angle of Descent Nonprecision Approaches

Some airlines have adopted a "constant angle of descent" technique for nonprecision approaches. This technique involves descending on a constant descent angle toward the runway and meeting all of the crossing restrictions of the nonprecision approach procedure while avoiding intermediate level-offs. For this technique, the crossing altitudes depicted on the approach chart are used only as the bottom portion of a window through which the airplane passes as it descends. In most cases, the descent angle is about 3°, except in instances in which terrain or obstructions require a steeper descent. Because of terrain factors, some currently approved nonprecision approaches are not amenable to being flown with a constant angle of descent method.

One method for flying a constant angle of descent, in the absence of a ground-based glideslope signal, involves the use of on-board flight management system (FMS) or GPS equipment that provides electronic guidance for a constant angle of descent. This method uses the same flight instrument and FD displays as with an ILS approach. The FMS or GPS equipment, one or both of which is widely installed in newer airplanes, provides precise, real-time information about airplane position.

Under FAA Order 8260.47, "Barometric Vertical Navigation Instrument Procedures Development," issued May 26, 1998, some airlines have received approval to use preprogrammed FMS/GPS approaches that include three-dimensional navigation guidance to the MAP, which is expressed as a barometric decision altitude. The advantages of this method include greater precision, lower pilot workload, and the ability to obtain FD guidance and couple the autopilot to fly the approach automatically. Pilots are not required to use step-down fixes, which removes the chance for misinterpreting the distance to the runway or the proper altitude for that distance and provides for a stabilized approach throughout the descent. The Safety Board concludes that, by providing vertical guidance along a constant descent gradient to the runway, the use of on-board FMS-and/ or GPS-based equipment can provide most of the safety advantages of a precision approach during a nonprecision approach. Therefore, the Safety Board believes that the FAA should require that all air carrier airplanes that have been equipped with on-board navigational systems capable of providing vertical flightpath guidance make use of these systems for flying nonprecision approaches whenever terrain factors allow a constant angle of descent with a safe gradient.

The Safety Board notes that it is likely that most air carrier airplanes will be equipped with on-board FMS and/or GPS equipment over the next several years and that the lack of such equipment may ultimately result in the loss of approach capability to certain runways for those airplanes not so equipped. Further, the Board acknowledges that terrain along the approach courses to some runways may preclude a constant angle of descent with a safe gradient, thus resulting in the loss of approach capability to certain runways. However, on the basis of the safety advantages of the constant angle of descent with vertical guidance versus step-down approaches, as demonstrated in the circumstances of this accident, the Safety Board believes that the FAA should require, within 10 years that all nonprecision approaches approved for air carrier use incorporate a constant angle of descent with vertical guidance from on-board navigation systems.

For those airplanes not yet equipped with on-board navigational systems capable of providing vertical flightpath guidance, an alternative method allows pilots to approximate a constant angle of descent. This method requires using a published approach procedure that incorporates a defined point along the final approach course to begin a constant angle descent to the runway of about 3°; this descent point and descent angle also fulfill the minimum crossing altitudes at each step-down fix of the nonprecision approach. If pilots are provided a tabular means of cross-referencing the distance from the runway (measured by DME) and the proper altitude for that distance, they can adjust the airplane's rate of descent to approximate a constant angle. The advantages of this method include greater awareness of the airplane's position on the approach path and a more stabilized approach, but there is additional workload involved in the cross-referencing of altitude and distance.

In Safety Recommendation A-96-128, issued on November 13, 1996, the Safety Board asked the FAA for the incorporation of constant angle descents instead of step-down criteria. The FAA indicated that it has made progress in providing some of the information pilots need to approximate a constant angle of descent (descent angles and gradients to the runway from a defined starting point). However, the FAA continues to provide insufficient information on approach charts to cross-reference DME distances and altitudes.

Thus, the Safety Board concludes that the safety of executing a nonprecision approach using the constant angle of descent, or stabilized descent technique, would be enhanced by adding to approach charts the cross-referenced altitudes versus distance from the airport. Therefore, the Safety Board believes that the FAA should include, in nonprecision approach procedures, tabular information that allows pilots to fly a constant angle of descent by cross-referencing the distance from the airport and the barometric altitude.

2.8.2 Safety Aspects of Enhanced Ground Proximity Warning Systems

At the time of the flight 801 accident, no Korean Air airplanes were equipped with enhanced GPWS nor were they required to be so equipped. Further, enhanced GPWS was not available for the 747-300 at the time of the accident.

The Safety Board notes that postaccident enhanced GPWS simulations conducted by AlliedSignal indicated that, if flight 801 had been equipped with enhanced GPWS, an aural “CAUTION TERRAIN” warning and a yellow visual terrain depiction on the color weather radar display would have been issued about 60 seconds before impact. An aural “TERRAIN TERRAIN” and “PULL UP” warning and a red visual terrain depiction on the weather radar scope would have been issued about 45 seconds before impact and would have sounded continuously until completion of a successful escape maneuver or impact.

Safety Recommendation A-96-101, issued on October 16, 1996, asked the FAA to examine the effectiveness of enhanced GPWS equipment and, if found effective, require all transport-category aircraft to be equipped with an enhanced GPWS that provides pilots with an early warning of terrain. In a May 4, 1999, letter to the Safety Board, the FAA stated that it issued an NPRM in August 1998 to require terrain awareness and warning system (TAWS) equipment (the name used in the NPRM for enhanced GPWS) on all civil turbine-powered aircraft with six or more passenger seats within 4 years of the issuance of a final rule. Pending the Board’s evaluation of the FAA’s completed action, Safety Recommendation A-96-101 was classified “Open — Acceptable Response” on July 13, 1999.

However, on May 12, 1999, the Safety Board expressed concern that the 4-year installation time frame was too long for retrofitting enhanced GPWS to existing turbine-powered airplanes that currently lack any GPWS protection. As a result, the Board issued Safety Recommendation A-99-36, urging the FAA to shorten the proposed installation period for these airplanes to 3 years (with a completion deadline of May 2002).[220]

In a July 26, 1999, response to the Safety Board, the FAA indicated that it was “committed to installing and using TAWS as expeditiously as possible.” The FAA stated that the final rule would require installation of TAWS within 1 year after the effective date on new-production airplanes and within 4 years for existing airplanes. The FAA added that the installation timetable was based on “product availability” and the “manufacturing approval process.”

The Safety Board notes that, on August 16, 1999, the FAA issued a technical standard order for TAWS equipment (specifications and installation requirements) and that the proposed final rule for TAWS installation was scheduled to be issued by March 2000. The Board acknowledges the FAA’s progress to date on TAWS issues but notes with disappointment that the 2005 installation deadline is 3 years longer than urged in Safety Recommendation A-99-36 for existing airplanes that are not currently required to have a GPWS. The Board continues to urge that the installation of enhanced GPWS be expedited not only for those airplanes covered by Safety Recommendation A-99-36 but also for the transport-category airplanes covered by Safety Recommendation A-96-101. Pending further action by the FAA, the Safety Board classifies Safety Recommendations A-96-101 and A-99-36 “Open — Acceptable Response.”

2.8.3 Terrain Depiction on Approach Charts

Approach chart vendors use various methods of depicting obstructions and high terrain on approach charts. On the plan view,[221] some vendors use contour lines and color shading for various height gradients and symbols for high obstructions, and others use broader colored areas with the minimum sector altitude for obstacle clearance printed over each area. However, no chart vendor depicts terrain or obstructions on the profile view,[222] which depicts the inbound approach course descent profile from an initial approach fix to a landing or missed approach. Other than the depiction of certain obstruction heights, there is no FAA requirement or standardized format to depict terrain on approach charts. The Safety Board notes that Nimitz Hill was not depicted on the Guam runway 6L ILS approach chart.

During an instrument approach, pilots generally refer to the plan view until they are established on the inbound approach course, usually on the intermediate and final approach segments. Once on the inbound approach course, pilots generally shift their attention on the approach chart from the plan to the profile view. Thus, the Safety Board concludes that terrain depiction on the profile view of approach charts could result in increased flight crew awareness of significant terrain on the approach path. The Board recognizes that logistical problems may be associated with obtaining and including this information and that not all users agree that obstacle depiction on the profile view is necessary and helpful. (See section 1.18.4.2.) Nevertheless, the Safety Board believes that the FAA should evaluate the benefits of depicting terrain and other obstacles along a specific approach path on the profile view of approach charts and require such depiction if the evaluation demonstrates the benefits.

2.8.4 User Review of Instrument Procedures

Charting companies that publish instrument procedures receive the pertinent information from the FAA on its Form 8260. This form includes data for the terminal area as well as final approach and missed approach standards for a specific instrument procedure. The manager of the FAA's Western Flight Procedures Development Branch testified at the Safety Board's public hearing that, when an approach procedure is completed but before it is published, the procedure is distributed to industry user groups, including ALPA, the Air Transport Association, the Aircraft Owners and Pilots Association, and airport operators, for review. The manager stated that the purpose of this user review is to ensure that the final product is safe, accurate, and intelligible. The Safety Board agrees with and endorses this practice. However, the Board notes that the FAA does not provide user groups with the approach procedure in its final, graphical form as it will be published and used. Rather, user groups are only given FAA Form 8260, which describes the approach in words and numbers.

Industry user groups, including ALPA (according to its submission to the Safety Board regarding this accident), have stated that the format of FAA Form 8260 makes it difficult for them to evaluate the procedure. Thus, the Safety Board concludes that valuable user group reviews of proposed new instrument procedures are hampered by the format in which the information is disseminated; thus, user groups may not be able to effectively evaluate whether a procedure is safe, accurate, and intelligible. Therefore, the Safety Board believes that the FAA should provide user groups, along with Form 8260, draft plan and profile views of instrument procedures to assist the groups in effectively evaluating proposed new procedures.

2.9 Oversight Issues

2.9.1 Korean Air

As discussed in sections 1.17.2.3 and 1.17.5.1, Korean Air established a CRM program and undertook several other safety initiatives in response to previous accidents. The company also had supervisor briefing and airport familiarization programs, both of which exceeded Korean regulatory requirements. (For more information about these programs, see section 1.17.3.)

The Safety Board recognizes that these efforts indicated a positive approach to safety. However, the supervisor briefing, which could have assisted the flight crew in preparing for the approach, did not review important items, such as NOTAMs or the currency of approach charts. Also, the airport familiarization video did not adequately prepare the crew for the possibility of a nonprecision approach in IMC, nor did it note that the DME was not colocated with the localizer. Further, as discussed previously, some of Korean Air's training and operational procedures, such as the limited number and variety of approach scenarios, lack of an interactive role for the nonflying pilot, and lack of documented cockpit approach procedures that clearly defined crewmember duties, contributed to the flight crew's deficiencies in this accident.

Korean Air experienced a series of accidents (beginning before and continuing after the Guam accident) involving crew coordination and performance (see section 1.17.5). These accidents raise broader questions about the adequacy of the company's training and operational procedures. The airline did take action in response to some of these accidents to address the safety problems brought to light. However, the continued occurrence of crew error accidents called for a broad in-depth assessment of the airline's flight operations to determine how best to mitigate opportunities for such errors.

At the Safety Board's public hearing, the Korean Air Deputy Director of Flight Operations appeared to recognize that, before the accident at Guam, Korean Air had not been placing sufficient emphasis on flight safety and particularly on pilot training. He testified:

> Looking back upon this accident we feel that most of our management up to now has been [ ] perhaps too short-term, short-[sighted], and superficial in its nature. … from this point on for the purpose of ascertaining safe flight operations we plan to make long-term plans and spare no resources in [attaining] this final objective of flight safety. Accordingly, we will adjust our management systems and invest all the more heavily into training and program development.[223]

The Safety Board acknowledges that, since the Guam accident, Korean Air has taken significant management, operational, and flight crew training actions.[224] However, in light of the specific deficiencies that were discovered during the investigation of this accident and Korean Air's accident and incident history, the Safety Board concludes that, at the time of the flight 801 accident, there were underlying systemic problems within Korean Air's operations and pilot training programs that indicated the need for a broad safety assessment of these programs.

2.9.2 Korean Civil Aviation Bureau Oversight of Korean Air

The KCAB is charged with oversight of the Korean civil airlines. At the time of the accident, two KCAB operations inspectors were assigned to provide oversight of Korean Air's flight operations. Korean Air pilots who were designated by the KCAB as check airmen and examiners conducted flight instruction, check rides, and proficiency checks and issued type ratings. The KCAB inspectors provided an annual evaluation of the flight skills of the check airmen and examiners but did not observe proficiency checks or check rides on Korean Air's wide-body fleet.[225]

According to its director, the KCAB routinely conducts one annual safety inspection, four quarterly inspections, and an average of 40 random inspections of the airline each year. The director added that the two safety inspectors assigned to Korean Air at the time of the accident also had oversight duties at another Korean carrier.[226] Regardless of the number of inspections of Korean Air performed by the KCAB, its failure to identify and monitor trends within the airline that might be indicative of safety problems raises questions about the adequacy of KCAB's oversight of Korean Air. Further, KCAB officials acknowledged that the agency, because of personnel workload constraints, frequently relied on Korean Air to self-report corrective actions taken in response to KCAB inspections and did not confirm directly that identified problems had been addressed by the airline.

As previously noted, the syllabus for Korean Air's KCAB-approved simulator training program described the scenarios used in training, type ratings, and proficiency checks, and these scenarios were followed repetitively, without deviation, during training exercises. Further, the training and checking scenarios incorporated an inadequate number and variety of nonprecision approach procedures. As a result of the airline's rigid adherence to a curriculum that provided an inadequate variety of approaches, flight crews were inadequately prepared to conduct nonprecision approaches. Also, cockpit approach procedures (for example, for the flying and nonflying pilot roles) were taught anecdotally and were not documented. After the accident and discussions with Safety Board investigators, the KCAB asked Korean Air to modify its simulator training syllabus to include a diversity of approach scenarios and improve its CRM program. Korean Air stated that it complied with these requests.

Implementing and maintaining the highest levels of aviation safety requires an ongoing relationship between the regulator (in this case, the KCAB) and the airline (in this case, Korean Air). Each entity plays an essential role: one complies with standards of safety, and the other ensures that such compliance is maintained. One researcher described the role of the regulator as follows:[227]

> Regulators are uniquely placed to function as one of the most effective defen[s]es against organizational accidents. They are located close to the boundaries of the regulated system, but they are not of it. This grants them the perspective to identify unsatisfactory practices and poor equipment that the organization has grown accustomed to or works around.

The Safety Board acknowledges that, in October 1998, after several accidents and incidents following the crash of flight 801, the Korean Ministry of Construction and Transportation (of which the KCAB is a part) ordered a 6-month suspension of 138 flights on 10 of Korean Air's domestic routes and ordered it to reduce service on the Seoul-to-Tokyo route. The Safety Board further acknowledges that KCAB operations inspectors now assigned to Korean Air have type ratings in the airplanes that the airline operates. However, as discussed previously, at the time of the flight 801 accident, there were signs suggesting underlying systemic problems within Korean Air's operations and pilot training programs that indicated the need for a broad safety assessment of these programs. No such assessment was carried out by Korean Air or the KCAB before the accident. Thus, the Safety Board concludes that the KCAB was ineffective in its oversight of Korean Air's operations and pilot training programs.

2.9.3 Federal Aviation Administration Oversight of Korean Air and Assessment of Korean Civil Aviation Bureau

The FAA issues operations specifications to foreign air carriers operating into the United States pursuant to 14 CFR Part 129. The FAA also assigns a POI[228] to each foreign air carrier to provide oversight to that carrier. The POI for Korean Air at the time of the accident stated that oversight of foreign carriers under Part 129 included inspections of trip records and facilities in the United States and ramp inspections of airplanes and crews when they were in the United States or its territories. However, the POI stated that the FAA did not inspect, approve, or oversee a foreign airline's training program or any of its manuals or accomplish line checks or en route inspections on board foreign airlines. (There is no requirement that a foreign carrier provide the FAA POI with flight operations or training manuals.) The POI also stated that there was no formal interaction between the KCAB and the FAA regarding their respective oversight activities relating to Korean Air.

The Safety Board notes that the purpose of the FAA's International Aviation Safety Assessment (IASA) program is to ensure that foreign air carriers operating in the United States are receiving adequate oversight by their respective civil aviation authority (CAA). The FAA developed this program in response to an identified need to oversee foreign carriers operating to the United States; however, the FAA's assessment under that program is limited to an evaluation of the foreign CAA's ability to provide oversight in accordance with ICAO Annex 6 standards. The FAA does not directly assess whether foreign carriers are receiving such oversight or are complying with Annex 6. When the FAA assessed the KCAB in 1996, the FAA concluded that the KCAB was capable of overseeing Korean air carriers in accordance with ICAO safety standards, and Korea was therefore given a Category I rating (the highest rating of the three IASA categories). The FAA indicated that it would reassess a country that has air carriers operating into the United States if there was any reason to question whether that country was meeting its international safety oversight obligations.

The substantial number of Korean Air crew-related accidents and incidents, the deficiencies in Korean Air's pilot training program, and the lack of documented cockpit procedures suggest that Korean Air had not fully complied with the intent of paragraph 9.3.1 of ICAO Annex 6, which states that operators "shall establish and maintain a ground and flight training program … which ensures that all flight crew members are adequately trained to perform their assigned duties. [The training program] shall also include training in knowledge and skills related to human performance and limitations … [and] shall ensure that all flight crew members know the functions for which they are responsible and the relation of those functions to the functions of other crew members."

The reliability of the FAA's assessment and rating of a country's CAA under the IASA program is becoming ever more important in light of increases in code-sharing and other alliances involving U.S. and foreign carriers. U.S. carriers are likely to view a positive assessment by the FAA and the resulting Category I rating as an indication that the country's airlines are receiving adequate oversight and are therefore maintaining an adequate level of safety. However, even though Korea had received and maintained a Category I rating, the evidence developed in this investigation (including that only two operations inspectors were assigned to Korean Air and that neither was type rated for the 747, as well as the deficiencies in the KCAB's oversight of Korean Air) and Korean Air's accident and incident record (both before and after the flight 801 crash) suggest that the FAA's IASA program was not adequate in its scope and depth to determine the capacity of the KCAB to fully assess Korean Air's level of safety or ensure that Korean Air was receiving adequate oversight. The Department of Transportation Office of Inspector General's (DOT/IG) audit report, titled *Aviation Safety Under International Code Share Agreements*, reached a similar conclusion. The DOT/IG report noted that the FAA's assessment under the IASA program "is quite different from a judgment about the safety practices of an individual carrier." The report further noted that the "FAA is itself a civil aviation authority that meets international standards, but that is materially different from a conclusion that all U.S. carriers therefore follow sound safety practices."

The Safety Board concludes that the FAA's IASA program (which evaluates a foreign CAA's ability to provide adequate oversight for its air carriers) is not adequate to determine whether foreign air carriers operating into the United States are maintaining an adequate level of safety. The Board notes that the DOT/IG's audit report recommended that U.S. carriers perform safety assessments of foreign carriers as a condition of approval to enter into code share agreements and that the FAA should consider the results of those assessments when performing IASA reviews. Further, the Safety Board believes that the FAA should consider the accident and incident history of foreign air carriers as a factor when evaluating the adequacy of a foreign CAA's oversight and whether a reassessment may be warranted.

2.9.3.1 Independent Accident Investigation Authority

The entity responsible for investigating aviation accidents and incidents in Korea is an office within the KCAB known as the Aviation Safety Division. Thus, Korea has no independent accident investigation authority. Experience has shown that an accident investigation authority that is not independent of the regulatory authority may not be as objective as necessary to identify and recommend changes. A proper accident investigation requires a review of the practices and procedures of the responsible regulatory agency and their possible role in the accident. Because the results of such an assessment may necessitate conclusions and recommendations that are critical of, or adverse to, the regulatory agency or its officials, many countries have concluded that no accident investigation entity could fully perform such a function unless it was separate and independent from the regulatory agency.

Annex 13 to the Convention on International Civil Aviation (paragraph 5.4) states that "the accident investigation authority shall have independence in the conduct of the investigation and have unrestricted authority over its conduct." On November 21, 1994, the Council of the European Union (EU) adopted a directive that specifies that EU Member States shall ensure, by November 21, 1996, that aviation accident and serious incident investigations are conducted or supervised by a permanent body or entity that is functionally independent of the national aviation authorities responsible for regulation and oversight of the aviation system. All EU members have complied with, or are in the process of complying with, the intent of this directive.[229] The Safety Board concludes that an independent accident investigation authority, charged with making objective conclusions and recommendations, is a benefit to transportation safety.

2.10 Flight Data Recorder Documentation

The Safety Board was unable to validate data from 11 retrofitted sensors on the accident airplane's FDR because Korean Air lacked complete and accurate documentation information for them. Although the data from the retrofitted sensors were not critical in the investigation of this accident, the data might have been important under other accident circumstances. For FDR data to be useful during an accident investigation, accurate documentation that is readily available to investigators after an accident is needed.

After taking delivery of an airplane from a manufacturer, many airlines provide additional data to be recorded on the FDR by retrofitting the airplane with additional sensors or recording additional data from a flight data acquisition unit. Such retrofits are often mandated by the governing CAA. In addition to the flight 801 accident, the Safety Board has investigated several other recent accidents in which airlines were unable to provide accurate and complete information from a retrofitted FDR because the airlines were unable to provide FDR documentation necessary for a complete and thorough readout.[230] Thus, the Safety Board often lacked critical data for a reconstruction of the airplane's motion and the flight crew's performance, which prolonged some investigations.

The Safety Board has long been concerned about inadequate FDR documentation. Since the early 1970s, the Board has made recommendations to improve FDR data verification and documentation. In 1991, concerns about the airworthiness of FDRs resulted in two safety recommendations to the FAA (A-91-23 and -24) aimed at developing a permanent policy for FDR maintenance and record-keeping. Safety Recommendation A-97-30 asked the FAA to publish, by January 1998, a promised AC addressing the installation and maintenance of FDRs.

On October 5, 1999, the FAA issued AC 20-141, "Airworthiness and Operational Approval of Digital Flight Data Recorder Systems." The purpose of the AC is to provide "guidance on design, installation, and continued airworthiness of Digital Flight Data Recorder Systems." Appendix 1 to the AC, "Standard Data Format for Digital Flight Data Recorder Data Stream Format and Correlation Documentation," provides "a standard for the data stream format and correlation documentation that operators must maintain to aid accident investigators in interpreting recorded flight data." The appendix details how to develop a document for each airplane that would provide the detailed information needed by Safety Board investigators to transcribe each parameter recorded by an FDR.

The Safety Board is concerned that AC 20-141 was not finalized until more than 8 years after the issuance of Safety Recommendations A-91-23 and -24. Nonetheless, the Board is pleased that the AC is now final and that it will provide airlines with critical and necessary guidance to properly document FDR parameters and systems. As a result, information from FDRs will be provided in the format needed by the Board for a complete and accurate readout.

In addition to AC 20-141, ICAO Annex 6, Part I, "International Commercial Air Transport — Aeroplanes," includes Attachment D, Flight Recorders. Section 3 of the attachment, entitled "Inspections of flight data and cockpit voice recorder systems," provides guidance to Member States on the continued airworthiness of FDR systems, such as details on how to conduct annual checks of every FDR parameter, including recorded signal and transcribed engineering units. Paragraph 3.2.c states that "a complete flight from the FDR should be examined in engineering units to evaluate the validity of all recorded parameters." In addition, paragraph 3.2.d states "the readout facility should have the necessary software to accurately convert the recorded values to engineering units and to determine the status of discrete signals." If Korean Air had been following this ICAO guidance and performing annual checks on all of the FDR parameters for the accident airplane, the airline would have been able to determine the conversion equations necessary to complete an FDR readout or would have been able to discover and correct the FDR parameter documentation discrepancies.

As the number of international flights increases, the possibility of accidents involving foreign aircraft within the United States also increases. The Safety Board concludes that it is critical that thorough documentation of the information recorded by an FDR be available for foreign- or U.S.-registered air transport airplanes that fly into or out of the United States. In accordance with the interagency group on international aviation protocol, the Board will introduce AC 20-141 at the next ICAO flight recorder panel meeting, with a proposal that the AC be adopted as the international standard and recommended practice for FDR systems.

3 Conclusions

3.1 Findings

1. After the flight crew made an initial sighting of Guam, Korean Air flight 801 encountered instrument meteorological conditions as the flight continued on its approach to Guam International Airport.

2. Although flight 801 likely exited a heavy rain shower shortly before the accident, the flight crew was still not able to see the airport because of the presence of another rain shower located between Nimitz Hill and the airport.

3. By not fully briefing the instrument approach, the captain missed an opportunity to prepare himself, the first officer, and the flight engineer for the relatively complex localizer-only approach and failed to provide the first officer and flight engineer with adequate guidance about monitoring the approach; therefore, the captain's approach briefing was inadequate.

4. The captain's expectation of a visual approach was a factor in his incomplete briefing of the localizer approach.

5. For flights conducted at night or when there is any possibility that instrument meteorological conditions may be encountered, the failure to fully brief an available backup instrument approach compromises safety.

6. The Korean Air airport familiarization video for Guam, by emphasizing the visual aspects of the approach, fostered the expectation by company flight crews of a visual approach and, by not emphasizing the terrain hazards and offset DME factors, did not adequately prepare flight crews for the range of potential challenges associated with operations into Guam.

7. The challenges associated with operations to Guam International Airport support its immediate consideration as a special airport requiring special pilot qualifications.

8. Although the captain apparently became confused about the glideslope's status, the flight crew had sufficient information to be aware that the glideslope was unusable

for vertical guidance and should have ignored any glideslope indications while executing the nonprecision localizer-only approach.

9. Navigation receivers, including glideslope receivers, may be susceptible to spurious radio signals.

10. The captain may have mistakenly believed that the airplane was closer to the airport than its actual position; however, if the captain conducted the flight's descent on this basis, he did so in disregard of the DME fix definitions shown on the approach chart.

11 As a result of his confusion and preoccupation with the status of the glideslope, failure to properly cross-check the airplane's position and altitude with the information on the approach chart, and continuing expectation of a visual approach, the captain lost awareness of flight 801's position on the instrument landing system localizer-only approach to runway 6L at Guam International Airport and improperly descended below the intermediate approach altitudes of 2,000 and 1,440 feet, which was causal to the accident.

12. The first officer and flight engineer noted the ground proximity warning system (GPWS) callouts and the first officer properly called for a missed approach, but the captain's failure to react properly to the GPWS minimums callout and the direct challenge from the first officer precluded action that might have prevented the accident.

13. The first officer and flight engineer failed to properly monitor and/or challenge the captain's performance, which was causal to the accident.

14. Monitored approaches decrease the workload of the flying pilot and increase flight crew interaction, especially when experienced captains monitor and prompt first officers during the execution of approaches.

15. The captain was fatigued, which degraded his performance and contributed to his failure to properly execute the approach.

16. Korean Air's training in the execution of nonprecision approaches was ineffective, which contributed to the deficient performance of the flight crew.

17. U.S. air carrier pilots would benefit from additional training and practice in nonprecision approaches during line operations (in daytime visual conditions in which such a practice would not add a risk factor).

18. The Combined Center/Radar Approach Control controller's performance was substandard in that he failed to provide the flight crew with a position advisory when he cleared the flight for the approach, inform the flight crew or the Agana tower controller that he had observed a rain shower on the final approach path, and monitor the flight after the frequency change to the tower controller.

19. Strict adherence to air traffic control procedures by the Combined Center/Radar Approach Control controller may have prevented the accident or reduced its severity.

20. If the ARTS IIA minimum safe altitude warning system had been operating as initially intended, a visual and aural warning would have activated about 64 seconds before flight 801 impacted terrain, and this warning would have likely alerted the Combined Center/Radar Approach Control controller that the airplane was descending below the minimum safe altitude for that portion of the approach.

21. Sixty-four seconds would have been sufficient time for the Combined Center/Radar Approach Control controller to notify the Agana tower controller of the low-altitude alert, the tower controller to convey the alert to the crew of flight 801, and the crew to take appropriate action to avoid the accident.

22. The Federal Aviation Administration's quality assurance for the minimum safe altitude warning system was inadequate, and the agency's intentional inhibition of that system contributed to the flight 801 accident.

23. A substantial portion of the delayed emergency response was caused by preventable factors.

24. The delayed emergency response hampered the timely evacuation of injured persons, and at least one passenger who survived the initial impact and fire might not have died if emergency medical responders had reached the accident site sooner.

25. Improved formal coordination among Guam's emergency response agencies has not been implemented, and off-airport drills to identify and correct deficiencies in disaster response planning before an accident occurs have still not been conducted in the more than 2 years since the flight 801 accident.

26. Actions taken by Guam's emergency response agencies after the accident have been inadequate because they failed to ensure that emergency notifications and responses would be timely and coordinated.

27. Controlled flight into terrain accident awareness and avoidance training is an important accident reduction strategy and should be mandatory for all pilots operating under 14 Code of Federal Regulations Part 121.

28. By providing vertical guidance along a constant descent gradient to the runway, the use of on-board flight management system- and/or global positioning system-based equipment can provide most of the safety advantages of a precision approach during a nonprecision approach.

29. The safety of executing a nonprecision approach using the constant angle of descent, or stabilized descent technique, would be enhanced by adding to approach charts the cross-referenced altitudes versus distance from the airport.

30. Terrain depiction on the profile view of approach charts could result in increased flight crew awareness of significant terrain on the approach path.

31. Valuable user group reviews of proposed new instrument procedures are hampered by the format in which the information is disseminated; thus, user groups may not be able to effectively evaluate whether a procedure is safe, accurate, and intelligible.

32. At the time of the flight 801 accident, there were underlying systemic problems within Korean Air's operations and pilot training programs that indicated the need for a broad safety assessment of these programs.

33. The Korean Civil Aviation Bureau was ineffective in its oversight of Korean Air's operations and pilot training program.

34. The Federal Aviation Administration's International Aviation Safety Assessment program (which evaluates a foreign civil aviation authority's ability to provide adequate oversight for its air carriers) is not adequate to determine whether foreign air carriers operating into the United States are maintaining an adequate level of safety.

35. An independent accident investigation authority, charged with making objective conclusions and recommendations, is a benefit to transportation safety.

36. It is critical that thorough documentation of the information recorded by a flight data recorder be available for foreign- or U.S.-registered air transport airplanes that fly into or out of the United States.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the captain's failure to adequately brief and execute the nonprecision approach and the first officer's and flight engineer's failure to effectively monitor and cross-check the captain's execution of the approach. Contributing to these failures were the captain's fatigue and Korean Air's inadequate flight crew training. Contributing to the accident was the Federal Aviation Administration's intentional inhibition of the minimum safe altitude warning system at Guam and the agency's failure to adequately manage the system.

4. Recommendations

As a result of the investigation of the Korean Air flight 801 accident, the National Transportation Safety Board makes recommendations to the Federal Aviation Administration, the Governor of the Territory of Guam, and the Korean Civil Aviation Bureau.

To the Federal Aviation Administration:

Require principal operations inspectors assigned to U.S. air carriers to ensure that air carrier pilots conduct a full briefing for the instrument approach (if available) intended to back up a visual approach conducted at night or when instrument meteorological conditions may be encountered. (A-00-7)

Consider designating Guam International Airport as a special airport requiring special pilot qualifications. (A-00-8)

Disseminate information to pilots, through the Aeronautical Information Manual, about the possibility of momentary erroneous indications on cockpit displays when the primary signal generator for a ground-based navigational transmitter (for example, a glideslope, VOR, or nondirectional beacon transmitter) is inoperative. Further, this information should reiterate to pilots that they should disregard any navigation indication, regardless of its apparent validity, if the particular transmitter was identified as unusable or inoperative. (A-00-9)

Conduct or sponsor research to determine the most effective use of the monitored approach method and the maximum degree to which it can be safely used and then require air carriers to modify their procedures accordingly. (A-00-10)

Issue guidance to air carriers to ensure that pilots periodically perform nonprecision approaches during line operations in daytime visual conditions in which such practice would not add a risk factor. (A-00-11)

Develop a mandatory briefing item for all air traffic controllers and air traffic control (ATC) managers, describing the circumstances surrounding the performance of the Combined Center/Radar Approach Control controller in this accident to reinforce the importance of following ATC procedures. (A-00-12)

Require that all air carrier airplanes that have been equipped with on-board navigational systems capable of providing vertical flightpath guidance make use of these systems for flying nonprecision approaches whenever terrain factors allow a constant angle of descent with a safe gradient. (A-00-13)

Require, within 10 years, that all nonprecision approaches approved for air carrier use incorporate a constant angle of descent with vertical guidance from on-board navigation systems. (A-00-14)

Include, in nonprecision approach procedures, tabular information that allows pilots to fly a constant angle of descent by cross-referencing the distance from the airport and the barometric altitude. (A-00-15)

Evaluate the benefits of depicting terrain and other obstacles along a specific approach path on the profile view of approach charts and require such depiction if the evaluation demonstrates the benefits. (A-00-16)

Provide user groups, along with Federal Aviation Administration Form 8260, draft plan and profile views of instrument procedures to assist the groups in effectively evaluating proposed new procedures. (A-00-17)

Consider the accident and incident history of foreign air carriers as a factor when evaluating the adequacy of a foreign civil aviation authority's oversight and whether a reassessment may be warranted. (A-00-18)

To the Governor of the Territory of Guam:

Form, within 90 days, a task force comprising representatives from all emergency response agencies on the island, including the appropriate departments within the government of Guam, Federal Aviation Administration, Guam International Airport Authority, U.S. Navy, U.S. Air Force, U.S. Coast Guard, Federal Emergency Management Agency, and all other affected agencies, to define and coordinate emergency notification and response procedures to ensure that timely emergency notifications are made to all local and Federal agencies according to need, location, and response time capability. (A-00-19)

Require periodic and regularly scheduled interagency disaster response exercises, including an off-airport aircraft accident scenario, in addition to those response drills already required at Guam International Airport in accordance with 14 Code of Federal Regulations Section 139.325. (A-00-20)

To the Korean Civil Aviation Bureau:

Require Korean Air to revise its video presentation for Guam to emphasize that instrument approaches should also be expected and describe the complexity of such approaches and the significant terrain along the approach courses and in the vicinity of the airport. (A-00-21)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL, Chairman

JOHN A. HAMMERSCHMIDT, Member

ROBERT T. FRANCIS II,* Vice Chairman

JOHN J. GOGLIA, Member

GEORGE W. BLACK, JR., Member

January 13, 2000

*Vice Chairman Francis requested that the following concurring statement be added to this report:

"I concur in the report on Korean Air flight 801-a classic controlled-flight-into-terrain accident. I am troubled, however, by the failure to include a recommendation that urges (1) timely installation of terrain awareness and warning systems in accordance with the FAA's reasonable proposed schedule; (2) avoidance of any delay in the proposed regulatory schedule; and (3) encouragement by the FAA to aircraft operators to install this critical safety device in advance of the proposed regulatory timetable.

Notes and References

1. Unless otherwise indicated, all times are Guam local time, based on a 24-hour clock.

2. The island of Guam is a U.S. territory in the Pacific Ocean and is part of the Mariana Islands. Guam has an elected governor and a 21-member unicameral legislature. U.S. Naval and Air Force installations make up 35 percent of the island's area.

3. Six of the passengers were Korean Air flight attendants who were "deadheading," that is, traveling off duty.

4. Three passengers (including one deadheading flight attendant) initially survived the accident with serious injuries but died within 30 days after the accident. According to 14 Code of Federal Regulations (CFR) Section 830.2, such fatalities are to be included in the total number of fatal injuries. A passenger with serious injuries died at the U.S. Army Medical Center in San Antonio, Texas, on October 10, 1997, but is not officially listed as a fatality because the passenger's death occurred more than 30 days after the accident.

5. See table 1 in section 1.2 for the injury chart.

6. The captain began a scheduled round trip to Hong Kong on August 3, 1997, but his return flight was delayed because of inclement weather. As a result, the captain had to remain overnight in Hong Kong and fly back to Seoul (as a pilot) on the morning of August 4.

7. The self- and SOF briefings are required parts of Korean Air's flight crew predeparture procedures. See section 1.17.3 for additional information.

8. VOR/DME stands for very high frequency omnidirectional radio range/distance measuring equipment. DME is expressed in miles.

9. Appendix B contains the CVR transcript. The transcript expresses the times of the CVR comments and sounds in coordinated universal time (UTC). Guam local time is 10 hours ahead of UTC time.

10. The ILS is a precision approach system that provides lateral guidance (localizer) and vertical alignment (glideslope) with the runway. The system uses ground-based radio transmitters that provide both the localizer and the glideslope signals. See sections 1.6.2.3 and 1.10.2 for additional information.

11. TOD is the departing cruise altitude.

12. The FLAKE intersection is 7 DME from the NIMITZ VOR and is on the 242° radial. An intersection can be defined by the crossing of two radials or by a specific distance on a bearing from a navigational aid.

13. An ILS approach can either be flown as a "full ILS" precision approach or a localizer-only, nonprecision approach. The criteria for both approaches are often presented on the same chart. For information on how the accident flight crew was to execute the nonprecision, localizer-only approach for runway 6L, see section 1.10.3.1.

14. The accident flight was scheduled to remain on the ground at Guam for 3 1/2 hours and then return to Seoul at 0930 (0830 Seoul local time).

15. In the aviation industry, a "747 classic" refers to the -100, -200, -300, and -SP (special purpose) models of the Boeing 747 airplane. Classic 747s have three crewmember seats and mostly analog (mechanical) gauges.

16. ATIS information Uniform noted the Notice to Airmen (NOTAM) for runway 6L, which stated that the ILS glideslope was "out of service until further notice." See section 1.7.1.

17. The CERAP controller did not advise the flight crew of its position. FAA Order 7110.65, "Arrival Instructions," section 5-9-4, paragraph (a) states that a controller is to provide the flight crew with a "position relative to a fix on the final approach course. If none is portrayed on the radar display or if none is prescribed in the procedure, issue position information relative to the navigation aid which provides final approach guidance or relative to the airport."

18. The altitude alert system provides visual and aural signals when approaching or deviating from the selected altitude. See section 1.6.2.1 for more information.

19. A GPWS is designed to provide the flight crew with visual and aural warnings when proximity to terrain, closure rate, descent rate, bank angle, and glideslope deviation become excessive. For more information, see sections 1.6.2.2 and 1.18.2

20. According to FAA radar data and CVR information, the captain's call for the windshield wipers to be activated occurred when the airplane was in the vicinity of the outer marker, which was located 1.6 DME from the NIMITZ VOR.

21. This alert occurs when the GPWS computer determines that the barometric sink rate of the airplane, beginning at 2,450 feet above ground level (agl), exceeds the designed threshold sink rate value. The threshold value for approximately 200 feet agl is 1,200 feet per minute.

22. The Korean MOCT is similar in function to the U.S. Department of Transportation (DOT). The Korean Civil Aviation Bureau (KCAB), a division within the MOCT, is responsible for overseeing the Korean civil airlines. For more information on the KCAB, see section 1.17.6.1.

23. For information on Korean Air's airport familiarization video presentation program, see section 1.17.3.2.

24. The first officer from the July 4, 1997, trip to Guam also indicated that the captain had used the ground time between that flight and the return trip to sleep in a seat in the first class compartment.

25 . Korean Air's Level 3 Pilot English Test comprises written, listening, and oral sections. An ATC-related part in the listening section "tests correct understanding and proper usage of ATC transmissions, ATIS broadcasts, [and] ATC terminology/phraseology." All Korean Air pilots are required to pass this test.

26. The times in sections 1.5.1 through 1.5.3 are expressed in Seoul local time, based on a 24-hour clock.

27. For information on the CERAP facility, see section 1.10.1.1.

28. For information on the Agana tower facility, see section 1.10.1.3.

29. A cycle is one complete takeoff and landing sequence.

30. For general information on GPWS, see section 1.18.2.1. For information on previous safety recommendations on GPWS and related systems, see section 1.18.2.4.

31. Desensitizing changes the range of values to which the alerts respond to minimize nuisance warnings. Desensitizing does not suppress or cancel (inhibit) the alerts. A terrain closure rate must exceed 2,500 feet per minute to initiate a warning during the time that the terrain and pull up warnings are desensitized.

32. According to the Boeing 747 Operations Manual used by Korean Air, activation of the pull up alert (which was desensitized in the landing configuration) requires the recovery maneuver (see section 1.17.4.3) immediately unless daytime VFR conditions exist and a positive visual verification is made that no hazards exist. The operations manual further states that flight crews should respond to terrain, don't sink, sink rate, too low gear, and glideslope alerts by correcting "flightpath and/or airplane configuration to eliminate the cause of the aural alert."

33. The flight mode annunciator (FMA), although not a part of the ILS system, indicates the mode for the FD and autopilot. The NAV mode selector switch determines what a flight crew expects to see on the FMA. "Armed" is indicated with white letters on a black background; "capture" is indicated with black letters on a green background. The radio magnetic indicator is used to determine VOR passage if the needles are set to VOR (and not to the ADF).

34. The FD is equipped with command bars. In a precision approach, the command bars provide guidance to maintain the glideslope; in a nonprecision approach, the command bars typically provide guidance to maintain the desired vertical speed.

35. The maximums for zero fuel weight, takeoff weight, and estimated landing weight were 242,630, 377,777, and 265,306 kg, respectively.

36. NOTAMs are disseminated to flight crews to provide information about conditions or changes in any aeronautical facility, service, procedure, or hazard.

37. In surface weather observations, cloud bases are measured in feet agl.

38. The term "cell" is used to describe an area of precipitation depicted on radar.

39. Chaff is aluminum foil strips dropped by military aircraft as phony targets to confuse radars.

40. Although the FAA concluded that the outer marker was functioning properly, its aural alert was not heard on the accident airplane's CVR, and the CVR contained no indication that the flight crew had seen the flashing blue light of the marker beacon indicator. However, the alert would not have been audible and the indicator would not have been seen if the flight crew had turned off the marker beacon aural alert and the marker beacon indicator. The instruments and switches related to the ILS that were found in the wreckage did not indicate the operational status of the marker beacon aural receivers and indicators.

41. The tower controller said that, at the time of the accident, the lights for runway 6L were on step 2, and the medium intensity approach lights were on step 1 (the lowest of three approach light intensity settings). These settings were not changed until after the accident when Ryan flight 789 requested that the lights on runway 24R be changed from step 2 to 3. The controller documented the runway light settings about an hour after the Ryan flight had landed and said that no one had reset the runway lighting panel during that period.

42. Andersen AFB is located at the northeastern end of the island. It has two runways that are oriented in the same manner as those at Guam International Airport.

43. The FPS-93 long-range radar system is connected to an Air Traffic Control Beacon Interrogator-5 encoder, and the ASR-8 radar system is connected to an Air Traffic Control Beacon Interrogator-4 encoder.

44. Saipan is part of the Mariana Islands.

45. At the time of the accident, ATC facilities were classified according to the number of flight operations per hour. Level I had the lowest number of flight operations; Level V had the highest number. ATC facilities are now classified under a different system that considers other factors in addition to the number of flight operations per hour.

46. TACAN stands for tactical air control and navigation. It is the U.S. military's version of DME.

47. Secondary radars transmit interrogation pulses to a receiver aboard an aircraft. The radars display altitude and identity information sent from the aircraft in response.

48. Primary radar targets only detect radar energy reflected from the structure of the aircraft itself.

49. See section 1.18.1.2 for information on Safety Board recommendations regarding the MSAW system.

50. According to FAA Order 7210.3M, "Facility Operation and Administration," section 13-2-7, MSAW and conflict alert functions can be temporarily inhibited "when their

continued use would adversely impact operational priorities." The order also states that a brief written report should be sent to the FAA air traffic directorate whenever these functions are inhibited.

51. The Safety Board may hold a public hearing as part of its investigation into certain accidents to supplement the factual record of an accident investigation. The Board calls technical experts as witnesses to testify, and Board investigative staff and designated representatives from the parties to the investigation ask questions to glean factual information. The hearing is not intended to analyze any factual information for cause. The Board held a public hearing on this accident from March 24 to 26, 1998, in Honolulu, Hawaii (see appendix A). Five issues were addressed at this hearing: controlled flight into terrain (CFIT) accidents, operation of navigational devices at the Guam airport, MSAW systems and practices related to these systems, search and rescue operations, and U.S. and foreign government oversight of foreign air carriers operating into the United States.

52. Safety Board investigators and FAA representatives were not able to locate a NOTAM addressing the Guam MSAW system's inhibited status. However, the FAA stated that a NOTAM would not normally be issued for an inhibited MSAW system.

53. See section 1.18.1.1 for information on other postaccident MSAW-related actions taken by the FAA.

54. In July 1995 and April 1997, the FAA conducted standard evaluations of the Agana tower. In addition, internal biannual evaluations were conducted during July 1995 and June 1997. After these evaluations, labor hours were increased to provide dual coverage of ATC positions during peak traffic periods. Because of this action, Serco began recruitment for an additional air traffic controller in mid-July 1997. The Safety Board was advised during its on-scene accident investigation that, although approval from the FAA had not been received, an additional controller was hired on August 12, 1997.

55. D-BRITE is a radar display remote linked from approach control to the tower.

56. FAA Order 7110.65, "Air Traffic Control," paragraph 10-3-1(b), states that controllers are to declare, in a timely manner, a flight that is overdue.

57. A GPS is a navigation system that provides precise, real-time information about an airplane's position.

58. The 727-200 was equipped with Rockwell International/Collins Model 51RV-1 ILS receivers.

59. The Safety Board is not aware of any other approaches that use a VOR as a step-down fix on the final approach segment of a localizer-only approach.

60. The step-down approach technique requires pilots to cross specific navigational fixes at or above several altitudes while descending to the MDA, at which point the pilot either executes a landing or a missed approach.

61. Copies of these approach charts are contained in the Safety Board's public docket for this accident. The Board maintains a public docket for each accident it investigates. The docket is used to establish the permanent record of an accident.

62. The plan view is the approach viewed from above; the profile view is the approach viewed from the side.

63. See section 1.18.7.1 for safety recommendations regarding the need for improved FDR documentation.

64. The Safety Board ranks the quality of CVR recordings in five categories: excellent, good, fair, poor, and unusable. For a recording to be considered "good quality," most of the crew conversations need to be accurately and easily understood. The transcript developed from the recording might indicate several words or phrases that were not intelligible; such losses are attributed to minor technical deficiencies/momentary dropouts in the recording system or simultaneous cockpit/radio transmissions that obscure one another.

65. Apra Harbor is located 5 DME on the approach course.

66. Station refers to a specific location on the airplane, as measured from a data point. Examples include fuselage station, typically measured from a point forward of the nose of the aircraft, and wing station, typically measured from a point at the wing root and extending outward.

67. The captain did not advise Korean Air, before the July 28 to July 30, 1997, round trip flight from Seoul to San Francisco that he had been diagnosed with bronchitis and prescribed medications for the condition, nor did he receive medical approval from the company to conduct this trip. Korean Air's Operations Manual, chapter 4-12-4 (dated May 21, 1997), requires that a crewmember who "must be on duty under influence of medication, shall follow the direction of an Aeromedical Specialist." International Civil Aviation Organization (ICAO) Annex 1, section 1.2.6 (dated November 16, 1989), specifies that license holders should not exercise the privileges of their licenses and related ratings at any time when they are aware of any decrease in their medical fitness that might render them unable to safely exercise these privileges.

68. According to the Guam airport emergency response guidelines, ramp control is responsible for providing all communication/dispatch functions in the event of an emergency.

69. After the accident, GFD policy was changed to drain fire truck brake lines only during periodic maintenance to prevent moisture from contaminating the lines. The GFD chief stated that a fire truck would not be taken out of service without having another vehicle in its place.

70. The Federal Fire Department's Station No. 5 is responsible for providing fire protection to U.S. Naval facilities on Guam.

71. After the accident, the regional director of the Federal Emergency Management Agency stated that the agency would provide money to refurbish the command post vehicle.

72. Admittance times may be different than arrival times because patients received immediate emergency room treatment before being officially admitted to the hospital.

73. Title 14 CFR Section 139.325, "Airport Emergency Plan," paragraph (g)(4) and (5), requires the certificate holder, that is, the airport, to "at least once every 12 months, review the emergency plan with all the parties with whom the plan is coordinated … ensure that all parties know their responsibilities … and hold a full-scale airport emergency plan exercise at least once every three years …"

74. The report stated that water and foam were available on the fire trucks at the scene but that "water would have spread … fire caused by fuel" and "foam would have caused further injury to those with burns and/or open wounds." The report also added that airborne water buckets would have pushed the toxic gases and smoke onto rescuers.

75. At the time of the accident, no enhanced GPWS system had been certified for the 747-300 series airplane.

76. See Public Hearing exhibit 9F for detailed information regarding these spurious signal tests.

77. The FAA engineer indicated during his testimony that voices and music contain 90- and 150-Hz components.

78. Korean Air's Deputy Director of Flight Operations further testified that "…starting on the 1st of April [1998] the company is under contract to receive expert consultation of comprehensive nature from a well-known and well-respected international organization."

79. The increased requirements were a 2-year freeze period as a captain on small- and medium-sized aircraft in Korean Air's fleet, 500 landing cycles on small- and medium-sized fleet aircraft, 350 landing cycles on large fleet aircraft, and 4,000 hours of flight time with the company.

80. Regarding Korean Air's revised policy on slippery runway conditions, the Immediate Action Plan stated that "wind gusts are to be taken into account when computing maximum allowable cross/tailwinds, allowable wind conditions must be adjusted to take into account braking action categories … [and] auto land approaches, new minimum stopping distances … [and] improved guidelines for determining wet runways must be observed, and more stringent takeoff and landing restrictions for marginal runway conditions have been adopted."

81. According to Korean Air's Immediate Action Plan, "automation should be at the most appropriate level. The level used should permit both pilots to maintain a comfortable workload distribution and maintain situational awareness."

82. Korean Air decided to outsource all simulator training activities to FlightSafety Boeing. The details for this arrangement were finalized in June 1999. Korean Air expected that the outsourcing program would begin in the latter part of 1999.

83. STARs are routes established for arriving IFR aircraft. Their purpose is to simplify clearance delivery procedures and facilitate the transition between en route and instrument approach procedures.

84. Category II instrument approaches have minimums of 100 feet decision height (DH) and a runway visual range of 1,200 feet.

85. Korean Air used a 747-200 model simulator to train 747-100, -200, and -300 pilots.

86. According to Korean Air, the company began LOFT in 1992 using the 747-200. In 1993, this training was expanded to the 747-400 and the MD-82. The training eventually covered all aircraft types and models.

87. The purpose of this course is to increase team abilities to handle abnormal situations through cooperative efforts between flight and cabin crewmembers.

88. In a postaccident interview, the Deputy Director of Flight Operations stated that Korean Air had incurred 17 violations in 1996.

89. A Korean Air representative stated that the captain was responsible for reviewing applicable NOTAMs during the self-briefing and discussing any questions about them with the company dispatcher. According to the SOF, the flight crew did not indicate that there were NOTAMs regarding the flight. The SOF also indicated

that he was unaware of the NOTAM regarding the inoperative glideslope.

90. See section 1.18.8 for more information on 14 CFR Section 121.445 and safety recommendations to the FAA on special airport criteria and designation.

91. In this report, the term "landing briefing" is synonymous with "approach briefing."

92. The Boeing 747 Guidebook is a Korean Air procedures and technique training aid. It is published in Korean and English. The edition in effect at the time of the accident was dated August 1993.

93. Korean Air states that normal procedures " … are the recommended actions necessary to operate the airplane for each phase of flight. They enable the flightcrew to more readily memorize the required items, ensure that all necessary actions have been taken, and minimize the time required."

94. The constant angle of descent technique requires pilots to maintain a predetermined constant angle and constant rate of descent, which is generally calculated to be about 3°, except when terrain or an obstacle necessitates a steeper descent. When a ground-based glideslope signal is absent, pilots can fly the constant angle of descent approach by using flight management system (FMS) and GPS equipment for electronic guidance. (See section 1.10.3.1 for a description of the step-down technique.)

95. Some international air carriers have the PNF lead or prompt the PF through the nonprecision approach procedure by stating the next procedural change, including course, heading, altitude, time, visual contact, and MAP. Further, some air carriers have the captain serve as the PNF (until just before landing) and monitor the first officer's performance (as the PF) during the approach procedure.

96. Most U.S. airlines refer to this procedure as the escape maneuver.

97. Airclaims Limited is an aviation consulting firm that collects data, in part, for the aviation insurance industry. The Airclaims Limited database is recognized by the aviation industry as a definitive source for worldwide aviation accident information. Loss data for this comparison were retrieved from Airclaims Client Aviation System Enquiry database and were current as of August 10, 1999. Exposure data were retrieved from Airclaims Limited, *Jet Operator Statistics*, 1999, issue 1.

98. Some of these accidents occurred when Korean Air was known as Korean Airlines. For consistency, Korean Air is used throughout this section.

99. See *International Civil Aviation Organization (ICAO), Destruction of Korean Air Lines Boeing 747 on 31 August 1983, Report on the Completion of the ICAO Fact-finding Investigation, June 1993*.

100. As stated in section 1.17.2.3, Korean Air instituted a CRM training program in December 1986 as a result of this accident.

101. See National Transportation Safety Board. 1984. *Korean Air Lines, McDonnell Douglas DC-10-30, HL7339, SouthCentral Air, Piper PA-31-350, N35206, Anchorage, Alaska, December 23, 1983*. Aircraft Accident Report NTSB/AAR-84/10. Washington, DC.

102. See *Libyan Civil Aviation Authority, Korean Air McDonnell Douglas DC-10-30 Korean Registration ML-7328 crashed nearby Tripoli International Airport Southeast of Runway 27 on July 27, 1989*. Aircraft Accident Final Report.

103. According to Korean Air personnel, this accident resulted in upgrades of the Korean Air pilot training program, including increased instrument flight time requirements, additional GPWS awareness in simulator training, and the adoption of computer-based academic training.

104. This information was contained in an Airclaims Limited major loss record.

105. According to Korean Air, this accident led to an increased awareness of the importance of speed callouts during the approach phase of flight.

106. The KCAB subsequently suspended the captain's flying status for 1 year and the first officer's status for 6 months.

107. The KCAB subsequently suspended the captain's ATP certificate and the first officer's flying status for 1 year.

108. Delta Air Lines, Air Canada, and Air France suspended their code-sharing agreements with Korean Air after this accident.

109. In addition, as stated in section 1.6, the KCAB was responsible for approving Korean Air's Continuous Maintenance Program.

110. These designated check airmen were authorized by the KCAB to conduct proficiency checks and aircraft type rating checks. The KCAB conducted annual evaluations of the designated check airmen.

111. Virtually all countries (including South Korea) are signatory to the Chicago Convention Treaty, which established the standards and recommended practices

for international civil aviation. Annex 13 addresses aircraft accident and incident investigation.

112. Annex 6 addresses the standards and recommended practices for operation of aircraft.

113. The position title for POIs assigned to foreign carriers is International Geographic Inspector (Operations).

114. One accident that raised such concerns was the January 25, 1990, crash of an Avianca Boeing 707 in Cove Neck, New York, as a result of fuel exhaustion.

115. According to the FAA, about 600 foreign air carriers operate into the United States, and about 103 countries or regional country alliances have oversight responsibilities for air carriers that either operate into the United States or have applied to operate into the United States.

116. Paragraph 9.3.1 of ICAO Annex 6 states that operators "shall establish and maintain a ground and flight training program … which ensures that all flight crew members are adequately trained to perform their assigned duties. [The training program] shall also include training in knowledge and skills related to human performance and limitations … [and] shall ensure that all flight crew members know the functions for which they are responsible and the relation of those functions to the functions of other crew members."

117. This policy is defined in a notice published in the *Federal Register*, Volume 60, No. 210, October 31, 1995.

118. The FAA does not assess a country's compliance with Annex 13. The Safety Board notes that, during the Accident Investigation Group (AIG) divisional meeting held by ICAO from September 14 to 24, 1999, AIG delegates adopted a recommendation for the ICAO Council to take steps to expand the ICAO safety oversight audit program to include an assessment of a country's compliance with Annex 13. The program currently assesses a country's compliance with Annexes 1, 6, and 8.

119. The FAA indicated that, in August 1998, the agency's Administrator had approved the transition to Phase 2 but that the change would not take effect until publication of a notice in the *Federal Register*.

120. According to the DOT/IG report, the six airlines are American, Continental, Delta, Northwest, Trans World, and United.

121. The DOT/IG report indicated that a "code share team," comprising representatives from the DOT and the FAA, was developing recommendations to address many of the issues discussed in the audit report. The report noted that, once the recommendations are accepted by DOT and FAA management, additional time and effort would be required to develop policies and procedures to implement those recommendations.

122. The FAA indicated that one MSAW function — at the Aspen/Pitkin Airport in Colorado — was not in service because of the "large number of false low-altitude alerts in the mountainous terrain." The FAA also indicated that "aviators have been notified of this condition."

123. National Transportation Safety Board. 1973. *Eastern Air Lines, Inc. L-1011, N310EA, Miami, Florida, December 29, 1972*. Aircraft Accident Report NTSB/AAR-73/14. Washington, DC.

124. National Transportation Safety Board. 1990. *USAir Flight 105, Boeing 737-200, N283AU, Kansas City International Airport, Missouri, September 8, 1989*. Aircraft Accident Report NTSB/AAR-90/04. Washington, DC.

125. National Transportation Safety Board, *Controlled Collision With Terrain, Transportes Aereos Ejecutivos, S.A. (TAESA), Learjet 25D, XA-BBA, Dulles International Airport, Chantilly, Virginia, June 18, 1994*. Aircraft Accident Report NTSB/AAR-95/02. Washington, DC.

126. The Safety Board investigated another accident involving discrepancies with an MSAW system. On January 13, 1998, a Gates Learjet 25B, N627WS, operated by American Corporate Aviation, Inc., of Houston, Texas, crashed approximately 2 nm east of the runway 26 threshold at George Bush Intercontinental Airport in Houston, Texas, during an ILS approach. (See Brief of Accident FTW98MA096 for more information.) The investigation revealed, among other things, that the MSAW system at the airport was not configured in accordance with the guidance provided in FAA technical document NAS-MD-633, "Minimum Safe Altitude Warning." The Board identified two MSAW-related errors: the altitude computations for runway 26 were based on the ILS DH instead of the localizer-only MDA, and the ILS data should not have been used at all because other nonprecision approaches to the runway were available. At the time of the accident, the MSAW threshold altitude for runway 26 was incorrectly set to 100 feet agl. Proper application of the procedures contained in NAS-MD-633 would have resulted in a threshold setting of 402 feet agl. This accident is also included in the discussion of Safety Recommendations A-95-35 and A-99-36 in section 1.18.2.4.

127. The Safety Board also issued Safety Recommendation A-94-186, which asked the FAA to review the calculations establishing the runway threshold coordinates for all runways at Dulles International

Airport with respect to the air surveillance radar to verify proper alignment of the MSAW capture boxes. On November 20, 1995, the Safety Board noted that the FAA had completed its review of the calculations and adaptation values for runway threshold coordinates for all runways at the airport and had verified proper alignment of the capture boxes. Therefore, Safety Recommendation A-94-186 was classified "Closed — Acceptable Action."

128. According to FAA inspection records, the Guam CERAP ARTS IIA facility was reviewed in July 1995.

129. See Brief of Accident ATL95FA046 for more information.

130. FAA Order 7110.65, "Air Traffic Control," states that "…unless otherwise authorized, tower radar displays are intended to be an aid to local controllers in meeting their responsibilities to the aircraft operating on the runways or within the surface area." The order also states that "…local controllers at non-approach control towers must devote the majority of their time to visually scanning the runways and local area; an assurance of continued positive radar identification could place distracting and operationally inefficient requirements upon the local controller."

131. See Brief of Accident IAD97FA001 for more information.

132. For information on the GPWS installed on Korean Air flight 801, see section 1.6.2.2.

133. Radio altitude is derived from the radio altimeter, also called the radar altimeter. The radio altimeter does not require an accurate barometric pressure setting; rather, it displays the height above the ground by using time-varying frequency and measuring the differences in the frequency of received waves, proportional to time and height.

134. For information on the aural alerts that would have been generated by enhanced GPWS for flight 801, see section 1.16.1.

135. In the NPRM, the FAA used the term "TAWS" when referring to enhanced GPWS because the FAA expected that a variety of systems could be developed to meet the improved standards proposed in the NPRM.

136. An AC provides nonregulatory guidance to certificate holders for compliance with the FARs.

137. These airplanes were not required by the FARs to be equipped with a GPWS.

138. *Investigation of Controlled Flight Into Terrain, Aircraft Accidents Involving Turbine-Powered Aircraft with Six or More Passenger Seats Flying Under FAR Part 91 Flight Rules and the Potential for Their Prevention by Ground Proximity Warning Systems*, DOT-TSC-FA6D1-96-01, 1996.

139. *Investigation of Controlled Flight Into Terrain, Selected Aircraft Accidents Involving Aircraft Flying Under FAR Parts 121 and 135 Flight Rules and the Potential for Their Prevention by Enhanced Ground Proximity Warning System (EGPWS)*, DOT-TSC-FA6D1-96-03, 1996.

140. National Transportation Safety Board. 1971. *Southern Airways, Inc., Douglas DC-9-15, N92S, Gulfport, Mississippi, February 17, 1971*. Aircraft Accident Report NTSB/AAR-71/04. Washington, DC.

141. National Transportation Safety Board. 1972. *Northeast Airlines, Inc., McDonnell Douglas DC-9-31, N982NE, Martha's Vineyard, Massachusetts, June 22, 1971*. Aircraft Accident Report NTSB/AAR-72-04. Washington, DC.

142. National Transportation Safety Board. 1972. *Southern Airways, Inc., DC-9, N97S, Tri-State Airport, Huntington, West Virginia, November 14, 1972*. Aircraft Accident Report NTSB/AAR-72-11. Washington, DC.

143. For more information on the Bar Harbor, Henson, and Simmons Airlines accidents, see Briefs of Accident DCA85AA035, DCA85AA037, and DCA86AA021, respectively.

144. National Transportation Safety Board. 1992. *Bruno's, Inc., Beechjet 400, N25BR, Rome, Georgia, December 11, 1991*. Aircraft Accident Report NTSB/AAR/92-01/SUM. Washington, DC.

145. See Safety Recommendation A-94-187 in section 1.18.1.2 for additional information about this accident.

146. See section 1.18.2.3 for more information about this study.

147. Between the time of the Safety Board's August 1995 letter and the FAA's April 1997 letter, the Volpe study was issued, and an American Airlines CFIT accident involving traditional GPWS occurred. (This accident is discussed in the Safety Recommendation A-96-101, which is the next recommendation presented.)

148. Safety Recommendation A-95-35 was superceded by A-99-36.

149. The investigation of this accident was conducted by the Aeronautica Civil of the Government of Colombia, with assistance from the Safety Board. For more information, see the Aeronautica Civil of the Government of Colombia Aircraft Accident Report, *Controlled Flight*

Into Terrain, American Airlines Flight 965, Boeing 757-223, N651AA, Near Cali, Colombia, December 20, 1995.

151. "A Study of Fatal Approach-and-landing Accidents Worldwide, 1980–1996," *Flight Safety Digest*, February–March 1998. This study was also included as part of a special FSF report, "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents," *Flight Safety Digest*, November–December 1998 and January–February 1999.

152. The study's data indicated that, of the 287 approach and landing accidents, 108 occurred on initial approach, 82 on final approach, and 97 on landing.

153. Of the 287 accidents in the study, 8 were judged to have insufficient information available to determine a primary causal factor.

154. Omission of action/inappropriate action was identified in 69 accidents, lack of positional awareness in 52 accidents; flight handling in 34 accidents, "press-on-itis" in 31 accidents, and poor professional judgment/airmanship in 12 accidents.

155. According to the FSF report, "considering the causal groups, rather than individual factors, "crew" featured in 228 of the 279 accidents (82 percent) … ."

156. These conclusions and recommendations were presented at the FSF's Corporate Aviation Safety Seminar, held May 5 through 7, 1998.

157. The captain stated that only three CFIT accidents during that time period occurred on precision approaches and that these accidents experienced a probable failure of the glideslope receiver, a probable failure of the FD to capture, and a possible situation in which the autopilot was not coupled.

158. The captain also indicated that ICAO was considering whether to publish a manual on CFIT avoidance.

159. See section 1.18.2.4 for more information about this accident.

160. The Aeronautica Civil of the Government of Colombia issued the following CFIT-related recommendations to the FAA: (1) require that all approach and navigation charts used in aviation graphically portray the presence of terrain located near airports or flightpaths, (2) encourage manufacturers to develop and validate methods to present accurate terrain information on flight displays as part of a system of early ground proximity warning, (3) develop a mandatory CFIT training program that includes realistic simulator exercises that are comparable to the successful windshear and rejected takeoff training programs, and (4) evaluate the CFIT escape 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 operating sections of the approved operations manuals. In addition, the Aeronautica Civil recommended that ICAO evaluate and consider adopting the recommendations of the FSF's CFIT task force (see appendix C).

161. The Safety Board reiterated Safety Recommendation A-96-94 on July 15, 1997. See National Transportation Safety Board. 1997. *Uncontrolled Flight Into Terrain, ABX (Airborne Express), Douglas DC-8-63, N827AX, Narrows, Virginia, December 22, 1996*. Aircraft Accident Report NTSB/AAR-97/05. Washington, DC.

162. Angle-of-attack is the angle of the airplane wing to the relative wind.

163. The Safety Board issued this recommendation because Jeppesen Sanderson was changing the portrayal of terrain on some, rather than all, of its charts. Specifically, Jeppesen was revising approach charts only if they displayed terrain that was above 2,000 feet within 6 miles of an airport; local area charts were being revised only if they displayed terrain that was more than 4,000 feet above the plan view of an airport.

164. National Transportation Safety Board. 1991. *Controlled Flight Into Terrain, Markair Flight 3087, Boeing 737-2X6C, N670MA, Unalakleet, Alaska*. Aircraft Accident Report NTSB/AAR-91/02. Washington, DC.

165. For more information, see the Air Force's *Accident Investigation Board Report, United States Air Force CT-43A [Boeing 737], 73-1149, 3 April 1996, at Dubrovnik, Croatia.*

166. See *Air Line Pilots Association Report on Accident Involving Korean Air Flight 801 at Agana, Guam, on August 6, 1997*, dated June 24, 1998.

167. National Transportation Safety Board. 1996. *Collision With Trees on Final Approach, American Airlines Flight 1572, McDonnell Douglas MD-83, N566AA, East Granby, Connecticut, November 12, 1995*. Aircraft Accident Report NTSB/AAR-96/05. Washington, DC.

168. See National Transportation Safety Board. 1994. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 Through 1990*. Safety Study NTSB/SS-94/01. Washington, DC.

169. For a discussion of previous accidents in which the Safety Board determined that fatigue was a factor, see section 1.18.6.

170. Orasanu, Judith, Martin, Lynne, and Davison, Jeannie. *Errors in Aviation Decision Making: Bad Decisions or Bad Luck?* NASA Ames Research Center, Moffett Field, California. Presented to the Fourth Conference on Naturalistic Decision Making, Warrenton, Virginia, May 29-31, 1998.

171. National Transportation Safety Board. 1994. *In-flight Loss of Control, Leading to Forced Landing and Runway Overrun, Continental Express, Inc., Embraer EMB–120RT, N24706, Pine Bluff, Arkansas, April 29, 1993*. Aircraft Accident Report NTSB/AAR-94/02/SUM. Washington, DC.

172. All times for this accident are central standard time, based on a 24-hour clock.

173. Human fatigue in transport operations was listed as one of the Safety Board's May 1999 Most Wanted Transportation Safety Improvements.

174. National Transportation Safety Board. 1994. *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay, Cuba, August 18, 1993*. Aircraft Accident Report NTSB/AAR-94/04. Washington, DC.

175. At the public hearing on this accident, the chief crew scheduler for American International Airways testified that this flight assignment would have resulted in an accumulated flight time of 12 hours, which was within the company's "24-hour crew day policy."

176. The strobe light was to be used as visual reference during the approach. The flight crew was not advised, however, that the strobe light was inoperative.

177. National Transportation Safety Board. 1999. *Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue*. Safety Report NTSB/SR-99/01. Washington, DC.

178. Safety Recommendation A-89-1 asked the DOT to expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. Safety Recommendation A-89-2 asked the DOT to develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. Safety Recommendation A-89-3 asked the DOT to review and upgrade regulations governing hours of service for all transportation modes to ensure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues.

179. As of November 1999, the Safety Board had not received a response on this recommendation from the DOT.

180. The Board encountered problems extracting data from retrofitted FDRs recovered from the following accidents and incidents: Express One, Boeing 727, Orebro, Sweden, November 12, 1996; Millon Air, Boeing 707, Manta, Ecuador, October 22, 1996; ValuJet, DC-9, Miami, Florida, May 11, 1996; ValuJet, DC-9, Savannah, Georgia, February 28, 1996; ValuJet, DC-9, Nashville, Tennessee, February 1, 1996; ValuJet, DC-9, Nashville, Tennessee, January 7, 1996; Millon Air, DC-8, Guatemala City, Guatemala, April 28, 1995; and Air Transport International, DC-8, Kansas City, Missouri, February 16, 1995. The lack of adequate documentation of these FDR systems prevented accurate and complete readouts of the FDR data and, consequently, a clear understanding of the circumstances surrounding the accidents.

181. The FAA adopted rulemaking to require airlines to retrofit FDRs on most U.S.-registered aircraft.

182. National Transportation Safety Board. 1997. *Descent Below Visual Glidepath and Collision With Terrain, Delta Air Lines Flight 554, McDonnell Douglas MD-88, N914DL, LaGuardia Airport, New York, October 19, 1996*. Aircraft Accident Report NTSB/AAR-97/03. Washington, DC.

183. The first officer indicated his belief that LaGuardia should be designated as a special airport and that approaches to runways 13 and 31 were worthy of special pilot qualification requirements.

184. This rule was adopted in June 1980.

185. The version of AC 121.445 that was in effect at the time of the accident was dated June 1990.

186. Armed is indicated with white letters on a black background. Blank is indicated by an absence of letters.

187. Capture is indicated with black letters on a green background.

188. It is not clear why the first officer made this callout at this altitude. It is possible that the first officer may have intended the callout to mean that only 1,000 feet remained before reaching the 1,440-foot step-down altitude, or he may have confused 2,400 feet with 1,400 feet on the altimeter. It is also possible that the first officer may have believed that the DME was located on the airport and that the airplane was approaching a DME value at which the airplane could descend to 1,440 feet. (See section 2.4.1.3.2 for a discussion about possible DME confusion.)

189. The approach briefing is called a "landing briefing" on the Korean Air checklist card.

190. Testimony by Korean Air officials at the Safety Board's public hearing indicated that these items were taught in company flight crew training.

191. National Transportation Safety Board. 1994. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 Through 1990*. Safety Study NTSB/SS-94/01. Washington, DC, pp. 40–41.

192. Orasanu, J. "Decision-making in the Cockpit." In *Cockpit Resource Management*. 1993. Ed. E.L. Weiner, B.G. Kanki, and R.L. Helmreich. San Diego: Academic Press, p. 159.

193. The Safety Board notes that the raw data localizer and glideslope needles and off flags on the first officer's ADI and HSI would have been out of view because his navigation receiver was tuned to the VOR.

194. The Boeing 727 flight crew stated that no glideslope flags were visible and that the ADI glideslope needle was "centered."

195. An FAA flight check of the VOR and DME transmitters conducted on August 7, 1997, determined that the systems were functioning properly and within prescribed tolerances.

196. Human factors research has shown that a common decision-making error, especially in high stress and workload situations, is for people to tend to ignore evidence that does not support an initial decision. Human "operators tend to seek (and therefore find) information that confirms the chosen hypothesis and to avoid information or tests whose outcome could disconfirm it," which produces an "inertia which favors the hypothesis initially formulated." See Wickens, C. (1992). *Engineering Psychology and Human Performance*, 2nd Edition. Columbus, Ohio: Charles E. Merrill.

197. Korean Air's cockpit training procedures instructed the pilot flying a nonprecision approach (with the autopilot engaged) to program the autopilot/FD controls, including VERT SPEED and ALT SEL (altitude select), unless that pilot directed the nonflying pilot to do so. In addition, flight crews were trained that, while executing the approach profile, the flying pilot was to initiate all heading, course, and altitude changes, including selection of the step-down altitudes. The role of the nonflying pilot was to monitor and challenge if the flying pilot failed to follow proper procedures.

198. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 Through 1990*, pp. 47–49 and 55–59.

199. Gander, P.H., Gregory, K.B., Miller, D.L., Graeber, R.C., Connell, L.J., and Rosekind, M.R. (1998). "Flight Crew Fatigue V: Long-Haul Air Transport Operations." *Aviation, Space, and Environmental Medicine*, 69 (9, Section II, Supplement), pp. B37–B48.

200. Akerstedt, T. (1998). "Shift Work and Disturbed Sleep/Wakefulness." *Sleep Medicine Reviews*, 2(2), pp. 117–128.

201. National Transportation Safety Board. 1994. *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay, Cuba, August 18, 1993*. Aircraft Accident Report NTSB/AAR-94/04. Washington, DC, p. 135.

202. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 Through 1990*, pp. 23–28.

203. National Transportation Safety Board. 1994. *In-flight Loss of Control, Leading to Forced Landing and Runway Overrun, Continental Express, Inc., Embraer EMB-120RT, N24706, Pine Bluff, Arkansas, April 29, 1993*. Aircraft Accident Report NTSB/AAR-94/02/SUM. Washington, DC.

204. Dinges, D.F. "Napping Patterns and Effects in Human Adults." In *Sleep and alertness: Chronobiological, behavioral, and medical aspects of napping*. 1989. Ed. D.F. Dinges and R.J. Broughton. New York: Raven Press, p. 181.

205. Lavie, P. "To Nap, Perchance To Sleep — Ultradian Aspects of Napping." In Sleep and alertness: Chronobiological, behavioral, and medical aspects of napping. 1989. Ed. D.F. Dinges and R.J. Broughton. New York: Raven Press, pp. 114–117.

206. Investigation determined that, on July 27, 1997, the captain's personal physician diagnosed him with bronchitis and prescribed a medication that could be used as a sleeping aid. On July 28 through 30, the captain flew an international round trip between Korea and the United States. The combined effects of the captain's illness and his long trip across numerous time zones were likely to have provided disruptions to his sleeping schedule that might have continued to affect him at the time of the accident.

207. During training, Korean Air pilots performed two different NDB approaches; each was performed once, and neither incorporated DME. The pilots also performed the localizer approach to runway 14 at Kimpo once and the VOR/DME approach to runway 32 at Kimpo five times. The localizer and VOR/DME approaches used a DME that was colocated and frequency paired with approach navigational facilities located on the airport. Thus, the pilots were exposed to four nonprecision approaches during their training, and the VOR/DME approach to runway 32 at Kimpo was the only approach performed more than once.

208. National Transportation Safety Board. 1996. *Collision With Trees on Final Approach, American Airlines Flight 1572, McDonnell Douglas MD-83, N566AA, East Granby, Connecticut, November 12, 1995*. Aircraft Accident Report NTSB/AAR-96/05. Washington, DC.

209. The Safety Board found similar nonprecision approach-related factors in its investigation of the 1995 accident involving an American Airlines Boeing 757 on a nonprecision approach to Cali, Colombia; the 1990 accident involving a Markair Boeing 737 on a nonprecision approach to Unalakleet, Alaska; the 1989 accident involving a Flying Tigers Boeing 747 that crashed while executing an NDB approach to Kuala Lumpur, Malaysia; and the 1989 incident involving a USAir Boeing 737 executing a localizer backcourse approach to Kansas City, Missouri.

210. The Safety Board notes the Korean Air simulator training now incorporates a variety of approach scenarios, including approaches in which the DME is not colocated with an on-airport navigational facility and approaches involving countdown/count up DME procedures. Also, the simulator training now includes approaches likely to be encountered in the airline's domestic and international operations.

211. The controller was required to continue monitoring the flight because radar service had not been terminated in accordance with paragraph 5-1-13.

212. The CERAP controller was monitoring the EARTS (en route) radar scope, which had a functioning MSAW capability. However, this MSAW capability was based on a different algorithm than the disabled ARTS IIA MSAW system (see section 2.6.2). The ARTS IIA MSAW system compares the airplane's trajectory with the ILS glideslope. The EARTS system uses a single altitude (based on the lowest MDA for all nonprecision approaches to the runway) from the FAF to the point at which MSAW processing terminates (usually 1 mile from the runway threshold).

213. The Safety Board recognizes that the en route radar display was set to a range of 265 nm and therefore could not be used for effectively monitoring the final approach. The terminal radar display was set to a range of 60 nm and displayed the final approach course for runway 6L.

214. Although the CERAP controller told Safety Board investigators that his last observation of the target of flight 801 on the terminal radar display was when the airplane was 7 miles from the airport at an altitude of 2,600 feet, FDR and radar data do not support his statement. The data indicated that, when the CERAP controller instructed the flight to contact the Agana tower, the airplane was at an altitude of about 2,200 feet and maintained a continual descent. Therefore, the airplane was probably farther than 7 miles from the airport when the CERAP controller last observed the flight.

215. As previously stated, the purpose of the ground-based MSAW system is to provide air traffic controllers with a visual and an aural warning whenever an airplane descends, or is predicted to descend, below a prescribed minimum safe altitude. This information can then be relayed to the pilots so they can take remedial action.

216. For more information on this safety recommendation, see section 1.18.2.2.

217. The Safety Board is also disappointed that the aural MSAW alert could not be installed on the D-BRITE system at Guam in a timely manner because the FAA did not certify the system until April 1998, more than 1 year after it was delivered.

218. The airplane's landing gear had struck an oil pipeline on the side of the road and pushed portions of the pipeline into the road.

219. According to Korean Air's Director of Academic Flight Training, the company's CFIT awareness training consisted of a discussion of GPWS alerts in ground school. The director stated that no CFIT avoidance scenarios were included in the simulator training curriculum and that CFIT awareness materials were collected in a "read file" that was available to flight crews. The director stated that Korean Air had no formal CFIT training curriculum.

220. Safety Recommendation A-99-36 superceded A-95-35, which had asked the FAA to require all "turbojet-powered airplanes" with six or more passenger seats to be equipped with a GPWS. Safety Recommendation A-99-36 asked the FAA to require that all "turbine-powered" airplanes with six or more passenger seats not currently required to be equipped with GPWS to have an operating enhanced GPWS installed within 3 years.

221. The plan view shows the approach viewed from above.

222. The profile view shows the approach viewed from the side.

223. Korean Air officials subsequently asked that this statement be removed from the public record and disagreed that there were deficiencies in Korean Air's management approach. However, the statement may well have been an adequate assessment of the company's shortcomings, and the Safety Board is disappointed that Korean Air officials apparently failed to recognize this possibility.

224. As discussed in sections 1.17.1 and 1.17.2.4, Korean Air contracted for extensive flight crew training

services (including courses on decision-making, communications skills, and CRM), revised simulator curricula to include a variety of situations encountered during flight operations, increased the minimum flight hour and experience qualification requirements for captains (from 3,000 hours and 3 years to 4,000 hours and 5 years), began a worldwide pilot recruitment program, and set a goal of installing enhanced GPWS equipment on all Korean Air airplanes by the end of 2003.

225. According to the KCAB, its inspectors did observe proficiency checks and check rides on Korean Air's narrow-body fleet (including the MD-80 and the F.100).

226. According to the KCAB's director, the agency was authorized after the accident to hire nine additional employees, including five new inspectors, to bolster oversight activities.

227. Reason, J.T. (1997). *Managing the risks of organizational accidents*. Aldershot: Hampshire, England, p. 182.

228. The FAA's position title for POIs assigned to foreign carriers is International Geographic Inspector (Operations).

229. The FAA does not assess a country's compliance with any of the provisions of Annex 13, which addresses accident and incident investigation standards and practices. However, the Safety Board notes that, during the Accident Investigation Group (AIG) divisional meeting held by ICAO from September 14 to 24, 1999, AIG delegates adopted a recommendation for the ICAO Council to take steps to expand the ICAO safety oversight audit program to include an assessment of a country's compliance with Annex 13. (The program currently assesses a country's compliance with Annexes 1, 6, and 8.)

230. See section 1.18.7.1 for a listing of these accidents.

Appendix A

Investigation and Hearing

Investigation

The Safety Board was initially notified of this accident about 1200 eastern standard time on August 5, 1997 (about 0300 Guam local time on August 6). A full go-team was assembled and departed that evening from Andrews Air Force Base in Maryland for Fairchild Air Force Base in Washington. At Fairchild, the team boarded another airplane and arrived in Guam about 0830 Guam local time on August 7, 1997. Accompanying the team to Guam was Board Member George Black.

The following investigative teams were formed: Operations, Human Performance, Aircraft Structures, Aircraft Systems, Powerplants, Maintenance Records, Air Traffic Control, Survival Factors, Aircraft Performance, Meteorology, and Search/Fire/Rescue. Specialists were also assigned to conduct the readout of the flight data recorder (FDR) and transcribe the cockpit voice recorder (CVR) in the Safety Board's laboratory in Washington, D.C. The initial CVR transcript was produced in English. However, the CVR group subsequently produced a more detailed transcript in both the English and Korean languages.

Parties to the investigation were the Federal Aviation Administration (FAA); Korean Air Company, Ltd.; Boeing Commercial Airplanes Group; Pratt & Whitney; the National Air Traffic Controllers Association; and Serco Aviation Services, Inc. Assistance was also provided by the U.S. Navy and emergency response personnel in Guam.

In addition, an official from the Korean Civil Aviation Bureau (KCAB) was designated as the Korean Accredited Representative in accordance with the provisions of Annex 13 to the Convention on International Civil Aviation. Further, two air safety investigators from Australia's Bureau of Air Safety Investigations participated in the investigation as technical observers.

Hearing

A public hearing was conducted for this accident on March 24 through 26, 1998, in Honolulu, Hawaii. Presiding over the hearing was Vice Chairman Robert Francis. Parties to the public hearing were the FAA; Serco Aviation Services; Korean Air; Guam Civil Defense, Fire Department, and Police Department; U.S. Navy; International Civil Aviation Organization (ICAO) Controlled Flight Into Terrain Steering Committee; AlliedSignal; Jeppesen Sanderson, Inc.; and the Air Line Pilots Association.

Appendix B

Cockpit Voice Recorder Transcript

[FSF editorial note: The following transcript is as it appears in the U.S. National Transportation Safety Board (NTSB) accident report except for minor column rearrangement, addition of notes defining some terms that may be unfamiliar to the reader, conversion of coordinated universal time to local time and deletion of Korean-language translations.]

CAM	=	Cockpit area microphone voice source or sound source
RDO	=	Radio transmission from accident aircraft
NAV	=	Navigation-signal identifiers heard through aircraft audio system
CTR	=	Radio transmission from Guam center controller
TWR	=	Radio transmission from Guam tower controller
GPWS	=	Voice identified as aircraft mechanical voice
-1	=	Voice identified as captain
-2	=	Voice identified as first officer
-3	=	Voice identified as flight engineer
-?	=	Voice unidentified
*	=	Unintelligible word
( )	=	Questionable insertion
[ ]	=	NTSB editorial insertion
…	=	Pause

Time	Source	Content
0111:42	**NAV**	[sound of AJA NDB and the Nimitz VOR signals continue through end of recording]
0111:46	**CAM-?**	[several unintelligible words]
0111:51	**CAM-1**	I will give you a short briefing … ILS is one one zero three … Nimitz VOR is one one five three, the course zero six three, since the visibility is six, when we are in the visual approach, as I said before, set the VOR on number two and maintain the VOR. for the TOD, I will add three miles from the VOR, and start descent when we're about one hundred fifty-five miles out. I will add some more speed above the target speed. well, everything else is all right. in case of go-around, since it is VFR, while staying visual and turning to the right at …, request a radar vector. if not, we have to go to Flake … turn towards Flake … turning towards a course zero six two outbound heading two four two and hold as published. since the localizer glideslope is out, MDA is five hundred sixty feet and HAT is three hundred four feet. it was a little lengthy. this concludes my landing briefing.
0113:06	**CAM**	[sound of cough or sneeze]
0113:33	**CAM-1**	we better start descent.
0113:35	**CAM-2**	yes.
0113:38	**CAM**	[sound of several clicks]
0113:40	**RDO-2**	and Guam center … Korean eight zero one leaving level four one zero for two thousand six hundred.
0113:44	**CTR**	Korean air eight zero one roger.
0113:58	**CAM**	[sound similar to that of seat movement]
0114:30	**CAM**	[sound of several clicks]
0114:32	**CAM**	[sound similar to that of seat movement]
0114:35	**CAM-3**	here it is, landing data card.
0114:37	**CAM-1**	OK thank you.
0114:41	**CAM**	[sound of several clicks]
0114:55	**CAM-1**	altimeter two niner eight six, one hundred thirty-four knots [several unintelligible words]
0115:17	**CAM**	[sound of several loud clicks]
0115:54	**CAM**	[sound similar to that of seat movement]
0116:57	**CAM-1**	there is bunch of something.
0118:26	**CAM-?**	there … [several unintelligible words]
0119:22	**CAM**	[break in CVR audio, similar to that of tape splice]
0120:01	**CAM-1**	if this round trip is more than a nine-hour trip, we might get a little something. with eight hours, we get nothing. eight hours do not help us at all.
0120:20	**CAM-1**	they make us work to maximum, up to maximum …
0120:28	**CAM-1**	probably, this way [unintelligible words], hotel expenses will be saved for cabin crews, and maximize the flight hours. anyway, they make us (B-747) classic guys work to maximum.
0120:35	**CAM**	[sound similar to that of seat movement]
0121:13	**CAM-1**	eh … really … sleepy … [unintelligible words]
0121:15	**CAM-2**	of course.
0121:59	**CAM-2**	captain, Guam condition is no good.
0122:06	**CTR**	Korean air eight zero one information uniform is current at Agana now … altimeter two niner eight six.
0122:11	**RDO-2**	Korean … eight zero one is checked uniform.
0122:16	**CAM-2**	two nine eighty-six.
0122:26	**CAM-1**	uh, it rains a lot.
0123:35	**CAM-1**	[unintelligible words]
0123:45	**CAM-1**	request twenty miles deviation later on.
0123:47	**CAM-2**	yes.

0123:46	**CAM-1**	… to the left as we are descending.
0123:48	**CAM**	[sound similar to that of seat movement]
0124:00	**CAM-?**	[chuckling] … [several unintelligible words]
0124:02	**CAM-2**	don't you think it rains more? in this area, here?
0124:07	**CAM-1**	left, request deviation.
0124:08	**CAM-2**	yes.
0124:09	**CAM-1**	one zero mile.
0124:10	**CAM-2**	yes.
0124:14	**CAM**	[sound of three chimes, similar to that of passenger-seat-belt signal]
0124:30	**RDO-2**	Guam center … Korean eight zero one request deviation one zero mile left of track.
0124:35	**CTR**	zero one approved.
0124:36	**RDO-2**	thank you.
0125:03	**CAM-3**	descent checklist.
0125:05	**CAM-2**	(yes please).
0125:07	**CAM-3**	cabin pressurization set … landing data speed bug one two niner?
0125:13	**CAM-?**	set.
0125:15	**CAM-?**	one two niner.
0125:17	**CAM-?**	fuel set for landing [several unintelligible words] … normal
0125:22	**CAM-3**	seat belt?
0125:23	**CAM-1**	on.
0125:25	**CAM-3**	altimeters stand by.
0125:28	**CAM-?**	where is it? … [several unintelligible words] weather radar …
0125:35	**CAM-3**	two niner eight six.
0125:38	**CAM-?**	landing briefing completed …
0125:41	**CAM-?**	altimeter two niner eight six.
0126:09	**CAM-3**	[several unintelligible words] we are supposed to be going out right-hand side from here …
0126:12	**CAM-?**	yes, request please.
0126:18	**CAM-1**	going right-hand side, then getting out of the left-hand side. next is left-hand side …
0126:21	**CAM-3**	how about Guam condition?
0126:23	**CAM-3**	is it Guam?
0126:25	**CAM-3**	[several unintelligible words] it's Guam, Guam.
0126:27	**CAM-1**	[chuckling] good.
0126:31	**CAM**	[sound similar to that of seat movement]
0127:17	**CAM-3**	[several unintelligible words] … because …
0127:58	**CAM-3**	today weather radar has helped us a lot.
0127:59	**CAM-1**	yes, they are very useful.
0128:52	**CAM-?**	[several unintelligible words]
0128:54	**CAM-1**	request heading one sixty.
0128:56	**RDO-2**	Guam center, Korean eight zero one request right turn heading one six zero.
0129:08	**CTR**	say again?
0129:09	**RDO-2**	Korean eight zero six ah eight zero one maintain heading one six zero.
0129:15	**CTR**	eight zero one approved.
0129:16	**RDO-2**	roger.
0129:36	**CAM-1**	course zero six three.
0129:38	**CAM-2**	set.
0129:50	**CAM-1**	if we take this way,
0129:52	**CAM-3**	yes.
0129:56	**CAM-1**	we should be getting … onto the route.
0131:08	**CAM-3**	it is rising instead.
0131:10	**CAM-1**	yeh, you are right.
0131:17	**RDO-2**	Guam center Korean eight zero one clear of Charlie Bravo request radar vector for runway six left.
0131:31	**CTR**	Korean eight zero one fly heading one two zero.
0131:34	**RDO-2**	heading one two zero Korean one … eight zero one.
0131:39	**CAM-3**	approach checklist?
0131:41	**CAM-1**	approach checklist.
0131:42	**CAM-3**	inboard landing lights?
0131:43	**CAM-1**	on.
0131:44	**CAM-3**	radio and nav instruments?
0131:45	**CAM-1**	set and cross-check.
0131:46	**CAM-2**	set and cross-check.
0131:47	**CAM-3**	radio altimeters?
0131:48	**CAM-1**	set.
0131:49	**CAM-2**	set.
0131:50	**CAM-3**	three hundred …
0131:51	**CAM-1**	three oh four.
0131:52	**CAM-?**	three zero four.
0131:55	**CAM-3**	shoulder harness?
0131:55	**CAM-1**	on.
0131:56	**CAM-3**	approach checklist complete.
0132:11	**CAM**	[sound similar to that of seat movement]
0132:17	**CAM**	[sound similar to that of seat movement]
0132:24	**CAM**	[sound of several clicks]
0133:03	**CAM-1**	set number one ILS frequency.
0133:05	**CAM-?**	number one.
0133:05	**CAM-?**	correct?
0133:06	**CAM-?**	yes.

0133:06	**CAM-?**	one one zero three.
0133:07	**CAM-?**	one one zero three.
0133:09	**CAM-2**	set.
0133:11	**CAM-1**	roger.
0133:18	**CAM**	[sound of several loud clicks]
0133:32	**CAM**	[sound similar to that of seat movement]
0133:38	**CAM-1**	what's the number for Guam … seventeen?
0133:40	**CAM-2**	seventeen.
0133:47	**CAM-?**	[several unintelligible words]
0134:05	**CAM-1**	ya, there is a big CB over there to the left.
0134:07	**CAM-?**	[unintelligible words]
0134:23	**CAM-3**	is it going to be rough?
0134:24	**CAM-1**	it may be better at lower altitude.
0134:33	**CAM**	[sound of click]
0134:33	**CAM-2**	flaps one.
0135:17	**CAM**	[sound of rattle, similar to that of stabilizer trim]
0135:29	**CAM-1**	flaps one.
0135:30	**CAM-2**	flaps one.
0135:32	**CAM**	[sound of clicks]
0135:34	**CAM-2**	one nine nine.
0135:50	**CAM-1**	five.
0135:51	**CAM-2**	flaps five … one seventy-nine.
0135:53	**CAM**	[sound of click]
0136:13	**CAM**	[sound of rattle, similar to that of stabilizer trim]
0136:33	**CAM-?**	[several unintelligible words]
1537:07	**CAM-1**	INS DME display … [several unintelligible words]
0137:09	**CAM-?**	yeh.
0137:55	**CAM**	[sound of altitude alert]
0138:12	**CAM**	[sound of click]
0138:13	**CAM**	[sound of slight increase in wind background noise]
0138:34	**CAM**	[sound of loud clunk]
0138:37	**CAM-1**	flaps ten.
0138:37	**CAM-2**	yes sir, flaps ten.
0138:39	**CAM**	[sound of click]
0138:40	**CAM-2**	one fifty-nine
0138:49	**CTR**	Korean air eight zero one turn left heading zero niner zero join localizer.
0138:52	**CAM**	[sound of click]
0138:53	**RDO-2**	* heading zero nine zero intercept the localizer.
0138:57	**CAM-1**	turn to the *.
0139:09	**CAM**	[sound of rattle, similar to that of stabilizer trim]
0139:12	**CAM**	[sound of slight decrease in wind/ background noise]
0139:18	**CAM**	[sound of slight increase in wind/ background noise]
0139:20	**CAM-?**	oooh [surprised expression].
0139:23	**CAM**	[sound of slight decrease in wind/ background noise]
0139:25	**CAM-?**	cool and refreshing.
0139:28	**CAM-?**	[several unintelligible words]
0139:30	**CAM-2**	glideslope … [several unintelligible words] … localizer capture [several unintelligible words] glideslope … did.
0139:44	**CTR**	Korean air eight zero one … cleared for ILS runway six left approach … glideslope unusable.
0139:48	**RDO-2**	Korean eight zero one roger … cleared ILS runway six left.
0139:55	**CAM-3**	is the glideslope working? glideslope? yeh?
0139:56	**CAM-1**	yes, yes, it's working.
0139:57	**CAM-3**	ah, so …
0139:58	**CAM-?**	check the glideslope if working?
0139:59	**CAM-?**	why is it working?
0140:00	**CAM-2**	not usable.
0140:01	**CAM-3**	six D check, gear down.
0140:04	**CAM-1**	check …
0140:06	**CAM**	[sound of altitude alert]
0140:07	**CAM**	[sound of click]
0140:16	**CAM-?**	[several unintelligible words]
0140:20	**CAM**	[sound of clicks]
0140:21	**CAM**	[sound of increase in wind/background noise]
0140:22	**CAM-?**	glideslope is incorrect.
0140:33	**CAM-2**	approaching fourteen hundred.
0140:37	**CAM-1**	since today's glideslope condition is not good, we need to maintain one thousand four hundred forty. please set it.
0140:40	**CAM-?**	yes.
0140:42	**CTR**	Korean air eight zero one contact the Agana tower one one eight point one "ahn nyung hce ga sae yo" ["goodbye" in Korean language]
0140:47	**RDO-2**	"soo go ha sip si yo" ["take care" in Korean language] … one eighteen one.
0140:50	**CAM-3**	the guy working here probably was a GI in Korea before.
0140:52	**CAM-1**	yes.
0140:55	**RDO-2**	Agana tower Korean air eight zero one intercept the localizer six left.
0140:56	**CAM**	[sound of configuration-warning horn]
0140:57	**CAM**	[sound of altitude alert]

0141:01	**TWR**	Korean air eight zero one heavy Agana tower runway six left wind … at zero niner zero at seven … cleared to land … verify heavy Boeing seven four seven tonight.
0141:11	**CAM**	[sound of three clicks, similar to flap-handle movement]
0141:14	**RDO-2**	Korean eight zero one roger … cleared to land six left.
0141:18	**TWR**	Korean eight zero one heavy roger.
0141:20	**CAM**	[sound similar to that of seat movement]
0141:22	**CAM-1**	flaps thirty.
0141:23	**CAM-2**	flaps thirty.
0141:24	**CAM**	[sound of click, similar to that of flap-handle movement]
0141:24	**CAM**	[sound of configuration-warning horn]
0141:27	**CAM-2**	flaps thirty, confirmed.
0141:31	**CAM-2**	landing check.
0141:32	**CAM-1**	[several unintelligible words] … look carefully.
0141:33	**CAM-1**	set five hundred sixty feet. [noise increased].
0141:35	**CAM**	[sound of rattle, similar to that of stabilizer trim]
0141:35	**CAM-2**	set.
0141:37	**CAM-1**	landing check.
0141:40	**CAM-3**	tilt check normal.
0141:41	**CAM-1**	yes.
0141:42	**GPWS**	one thousand.
0141:43	**CAM-1**	no flags gear and flaps.
0141:44	**CAM**	[sound similar to that of seat movement]
0141:45	**CAM-3**	no flags gear and flaps.
0141:45	**CAM**	[sound of altitude alert]
0141:46	**CAM-1**	isn’t glideslope working?
0141:48	**CAM-1**	wiper on.
0141:49	**CAM-3**	yes, … wiper on.
0141:53	**CAM-2**	landing checklist.
0141:53	**CAM**	[sound similar to windshield wiper starts and continues to end of recording]
0141:55	**CAM-3**	ignition flight start flight start.
0141:59	**CAM-2**	not in sight?
0142:00	**GPWS**	five hundred.
0142:02	**CAM-3**	eh? [astonished tone]
0142:03	**CAM-?**	stabilize, stabilize.
0142:04	**CAM-1**	oh, yes.
0142:05	**CAM-3**	autobrake?
0142:07	**CAM-1**	minimum.
0142:07	**CAM-3**	minimum.
0142:08	**CAM-1**	landing gear down in green.
0142:09	**CAM-3**	landing gear down in green.
0142:09	**CAM-3**	speedbrakes armed.
0142:10	**CAM-?**	armed.
0142:11	**CAM-3**	no-smoke sign on?
0142:12	**CAM-1**	on course.
0142:12.81	**CAM-3**	flaps?
0142:13.64	**CAM-?**	thirty thirty green.
0142:14.13	**GPWS**	minimums minimums.
0142:14.70	**CAM-3**	hydraulics.
0142:15.45	**CAM-?**	uh, landing lights.
0142:17.15	**GPWS**	sink rate.
0142:18.17	**CAM-2**	sink rate, OK.
0142:19.04	**CAM-3**	two hundred.
0142:19.47	**CAM-2**	let’s make a missed approach.
0142:20.56	**CAM-3**	not in sight.
0142:21.07	**CAM-2**	not in sight. missed approach.
0142:22.18	**CAM-3**	go around.
0142:23.07	**CAM-1**	go around.
0142:23.77	**CAM**	[sound of autopilot-disconnect warning starts]
0142:23.84	**CAM-2**	flaps.
0142:24.05	**GPWS**	one hundred.
0142:24.84	**GPWS**	fifty.
0142:25.19	**GPWS**	forty.
0142:25.50	**GPWS**	thirty.
0142:25.78	**GWPS**	twenty.
0142:25.78	**CAM**	[sound of initial impact]
0142:28.65	**CAM**	[sound of tone]
0142:28.91	**CAM**	[sound of groans]
0142:30.54	**CAM**	[sound of tone]
0142:31.78	**CAM**	[sound of tone]
0142:32.53		**End of Recording**

CVR = Cockpit voice recorder
DME = Distance-measuring equipment
GI = Government issue (a member or former member of the U.S. armed forces)
GPWS = Ground-proximity warning system
HAT = Height above touchdown
ILS = Instrument landing system
INS = Inertial navigation system
MDA = Minimum descent altitude
NDB = Nondirectional beacon
TOD = Top of descent
VFR = Visual flight rules
VOR = Very-high-frequency omnidirectional radio

Appendix C

Flight Safety Foundation Study Recommendations

[FSF editorial note: The following are nine preliminary conclusions and associated recommendations of the Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force, as discussed in section 1.18.3.1 of the U.S. National Transportation Safety Board (NTSB) report on the Korean Air Flight 801 accident at Nimitz Hill, Guam, Aug. 6, 1997. The FSF ALAR Task Force nine preliminary conclusions and recommendations differ somewhat from the eight conclusions and recommendations in the task force's final reports, which were published in the November–December 1998 and January–February 1999 special issue of *Flight Safety Digest*: "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." The nine preliminary conclusions and recommendations presented in the NTSB report are as follows:]

Conclusion 1: Establishing and adhering to adequate standard operating procedures (SOP) and crew resource management (CRM) processes will improve approach and landing safety.

Recommendations:

- States should mandate, and operators should develop and implement, SOPs for approach and landing operations.
- Operators should develop SOPs that permit their practical application in a normal operating environment. The involvement of flight crews is essential in the development and evaluation of SOPs. Crews will adhere to SOPs that they help develop and understand.
- Operators should implement routine and critical evaluation of SOPs to determine the need for change.
- Operators should provide education and training that enhance flight crew decision-making and risk (error) management.
- Operators should develop SOPs regarding the use of automation in approach and landing operations and train flight crews accordingly.
- There should be a clear policy in all operators' manuals regarding the role of the pilot-in-command (PIC) in complex and demanding flight situations. Training should address the practice of transferring pilot-flying duties during operationally complex situations.

Conclusion 2: Improving communication and mutual understanding between air traffic control (ATC) services and flight crews of each other's operational environment will improve approach and landing safety.

ATC recommendations:

- Introduce joint training programs that involve both ATC personnel and flight crews to promote mutual understanding of such issues as procedures, instructions, operational requirements, and limitations; improve controllers' knowledge of the capabilities and limitations of advanced-technology flight decks; and foster improved communications and task management by pilots and controllers during emergency situations.
- Ensure that controllers are aware of the importance of unambiguous information exchange, particularly during in-flight emergencies. The use of standard ICAO phraseology should be emphasized.
- Implement procedures that require immediate clarification or verification of transmissions from flight crews that indicate a possible emergency situation.
- Implement procedures for ATC handling of aircraft in emergency situations to minimize flight crew distraction.
- Implement, in cooperation with airport authorities and rescue services, unambiguous emergency procedures and common phraseology to eliminate confusion.
- Develop, jointly with airport authorities and local rescue services, emergency training programs that are conducted on a regular basis.

Flight crew recommendations:

- Verify understanding of each ATC communication and request clarification when necessary.
- Report accurately, using standard ICAO phraseology, the status of abnormal situations and the need for emergency assistance.

Conclusion 3: Unstabilized and rushed approaches contribute to ALAs.

Recommendations:

- Operators should define the parameters of a stabilized approach in their flight operations manuals, including at least the following: intended flightpath, speed, power setting, attitude, sink rate, configuration, and crew readiness.

- Company policy should state that a go-around is required if the aircraft becomes destabilized during the approach.

- The implementation of certified constant angle, stabilized approach procedures for nonprecision approaches should be expedited globally.

- Flight crews should be trained on the proper use of constant angle, stabilized approach procedures. Flight crews should also be educated on approach design criteria and obstacle clearance requirements.

- Flight crews should "take time to make time" when the cockpit situation becomes confusing or ambiguous, which means climbing, holding, requesting vectors for delaying purposes, or performing a missed approach early.

Conclusion 4: Failure to recognize the need for and to execute a missed approach, when appropriate, is a major cause of ALAs.

Recommendations:

- Company policy should specify well-defined go-around gates for approach and landing operations. Parameters should include visibility minima required before proceeding past the final approach fix or the outer marker, assessment at the final approach fix or the outer marker of crew and aircraft readiness for the approach, and minimum altitude at which the aircraft must be stabilized.

- Companies should declare and support no-fault go-around and missed approach policies

Conclusion 5: The risk of ALAs is higher in operations conducted during low light and poor visibility, on wet or otherwise contaminated runways, and with the presence of optical physiological illusions.

Recommendations:

- Flight crews should be trained in operations involving these conditions before being assigned line duties.

- Flight crews should make operational use of a risk assessment tool or checklist to identify approach and landing hazards. Appropriate procedures should be implemented to mitigate the risks.

- Operators should develop and implement constant angle, stabilized approach procedures to assist crews during approach operations.

- Operators should develop and implement a policy for the use of appropriate levels of automation of navigation and approach aids for the approach being flown.

Conclusion 6: Using the radio altimeter as an effective tool will help prevent ALAs.

Recommendations:

- Education is needed to improve crew awareness of radio altimeter operation and benefits.

- Operators should install radio altimeters and activate "smart callouts" at 2,500, 1,000, and 500 feet; the altitude set in the decision height window; and 50, 40, 30, 20, and 10 feet for better crew terrain awareness.

- Operators should state that the radio altimeter is to be used during approach operations and specify procedures for its use.

Conclusion 7: When the PIC is the pilot flying and the operational environment is complex, the task profile and workload reduce the flying pilot's flight management efficiency and decision-making capability in approach and landing operations.

Recommendations:

- Operators should develop a clear policy in their manuals defining the role of the PIC in complex and demanding flight situations.

- Training should address the practice of transferring pilot flying duties during operationally complex situations.

Conclusion 8: Collection and analysis of in-flight parameters (for example, flight operations quality assurance programs) can identify performance trends that can be used to improve the quality of approach and landing operations.

Recommendations:

- Flight operations quality assurance should be implemented worldwide along with information-sharing partnerships, such as the Global Analysis and Information Network, British Airways Safety Information System, and FAA Aviation Safety Action Programs.

- Examples of flight operations quality assurance benefits (safety improvements and cost reductions) should be widely publicized.

- A process should be developed to bring flight operations quality assurance and information-sharing partnerships to regional airlines and business aviation.

Conclusion 9: Global sharing of aviation information decreases the risk of ALAs.

Recommendations:

- Deidentification of aviation information data sources should be a "cardinal rule" in flight operations quality assurance and information-sharing processes.

- Public awareness of the importance of information sharing must be increased through a coordinated, professional, and responsible process.

The Flight Safety Foundation [* ALAR] task force said that its conclusions and recommendations "must be translated into industry action" according to the following principles:

- cohesiveness across all aviation sectors and regions to participate jointly in the implementation process and

- commitment to a significant awareness campaign that will ensure availability of this information to participants in approach and landing operations worldwide so that they can play a part in improving safety within their "spheres of influence."

Air Transport Operations in Brazil Show Safety-improvement Trends

No accidents involving large commercial transport aircraft occurred in 1998 or 1999, and the 1997 rate of 0.82 hull-loss accidents per million departures compares with a rate of 1.2 hull-loss accidents worldwide and a rate of 4.3 hull-loss accidents for the Latin America and Caribbean region.

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FSF Editorial Staff

Aviation safety specialists from nations of South America, Central America, the Caribbean and Mexico have advocated an "integrated regional effort with a straightforward agenda" despite their difficulties in gaining access to adequate accident/incident data and in changing what they consider to be ingrained cultural aspects of aviation, said Capt. Marco A.M. Rocha Rocky, group flight safety officer, TAM Brazilian Airlines, and an organizing member of the Pan American Aviation Safety Team (PAAST). Rocky also is a member of the Flight Safety Foundation (FSF) International Advisory Committee, the International Air Transport Association (IATA) Regional Coordination Group (RCG) based in Miami, Florida, U.S., and the IATA Safety Advisory Committee (SAC).

The International Civil Aviation Organization (ICAO) has grouped for statistical purposes the nations of South America, Central America, the Caribbean and Mexico as the ICAO Latin America and Caribbean Statistical Region, and the PAAST steering committee currently is working to gain the participation of people throughout this region.[1] ICAO groups these nations and territories differently for air navigation purposes and for organizing the services of ICAO regional offices.

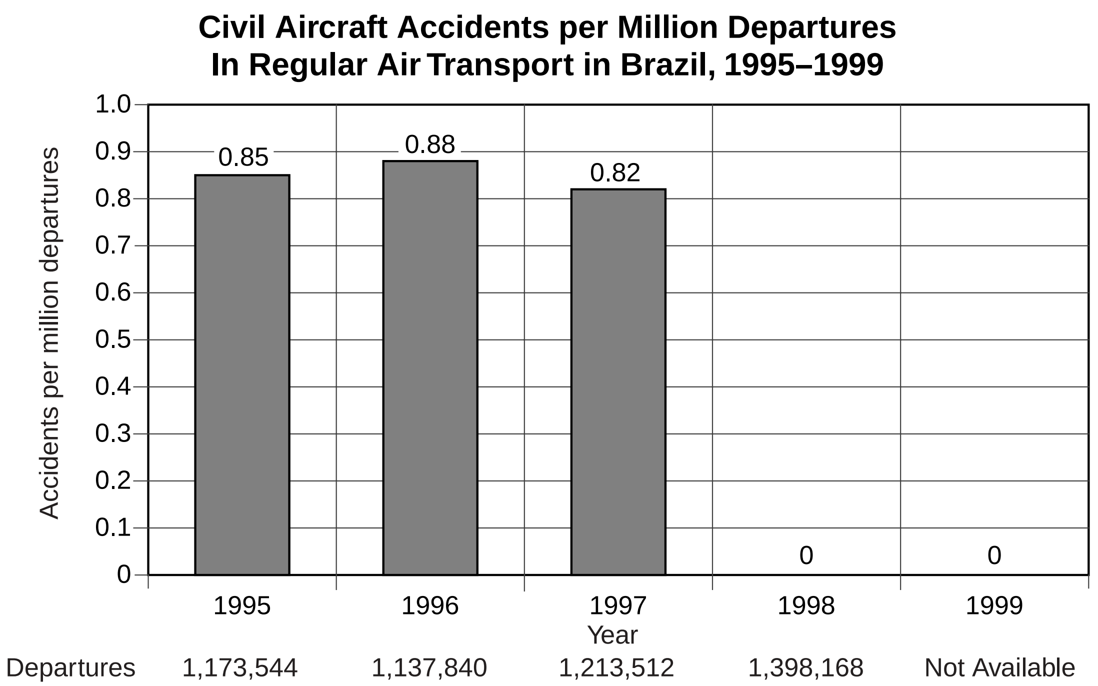
The latest data from Airclaims and Boeing Commercial Airplanes Group show a rate of 3.4 hull-loss accidents per million departures in South America and 4.3 hull-loss accidents per million departures for the Latin America and Caribbean region, which compares with a current worldwide rate of 1.2 hull-loss accidents per million departures. (A hull loss is damage to a commercial jet airplane that is substantial and beyond economic repair.)

Rocky said that accident data for Brazil, however, show the degree to which one nation's accident experience varies from the average of nations in South America or in the region defined by the PAAST steering committee.

"A region's accident rate does not represent reality for one country," Rocky said. "In 1998 and 1999, there were no commercial transport accidents in Brazil although the nation's airlines have flown more hours and sectors than in any previous year. On average, Brazilian airlines experienced 25 percent growth in these two years."

Data published by the Brazil Center for Investigation and Prevention of Aeronautical Accidents (CENIPA) and the Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA), included the following:

- Figure 1 (page 122) shows that in the category of large commercial jets in civil air transport (maximum gross weight greater than 60,000 pounds [27,216 kilograms]), the rates of accidents per million departures in Brazil



Note: Data for aircraft with maximum gross weight greater than 60,000 pounds (27,216 kilograms).

Source: Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA)

Figure 1

were 0.85 in 1995, 0.88 in 1996 and 0.82 in 1997. In 1998 and 1999, no accidents occurred in this category while the number of departures in 1998 increased 15.2 percent compared with 1997 (1999 departure data were not available);

- Figure 2 (page 123) shows that, in 1979, 408 civil aircraft accidents involving 202 fatalities occurred among Brazilian operators in all aircraft categories (the fleet size was not given for the years 1979 through 1986). In 1989, 242 accidents involving 146 fatalities occurred among a fleet of 7,890 aircraft in all categories (one accident per 33 aircraft). In 1999, 47 accidents involving 59 fatalities occurred among 11,719 aircraft (one accident per 249 aircraft), including 12 accidents in air taxi operations and one accident in regional air transport (Figure 3, page 123, and Figure 4, page 124);

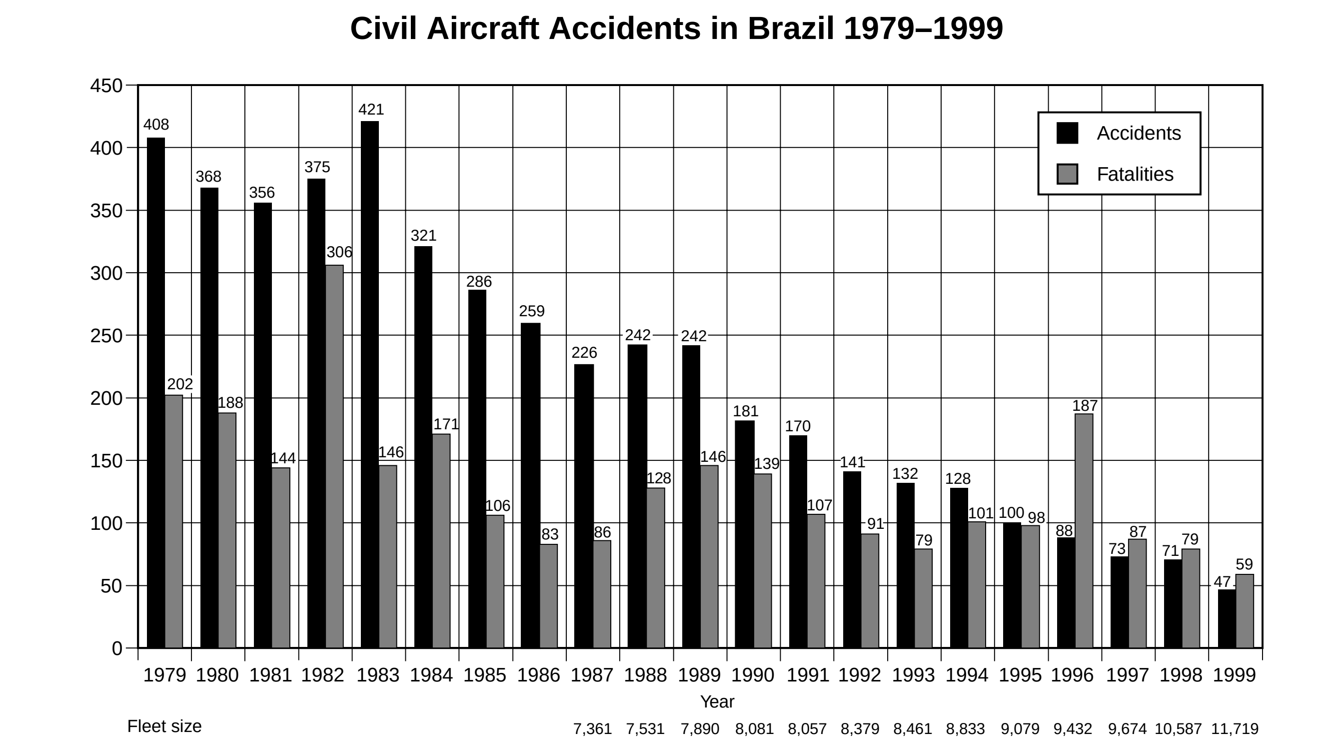
- Figure 5 (page 124) shows that at least four civil aircraft accidents occurred in each of Brazil's seven Regional Civil Aviation Services (SERACs) and the largest numbers of accidents and fatalities occurred in SERAC 4 (the states of São Paulo and Mato Grosso do Sul); and,

- Figure 6 (page 125) shows that 1999 data included 10 helicopter accidents involving 13 fatalities, which compared with 17 accidents involving 12 fatalities in 1998, and 15 accidents involving seven fatalities in 1997. All of the helicopter accidents occurred in three of the SERACs: four accidents involving nine fatalities in SERAC 3 (the states of Rio de Janeiro, Minas Gerais and Espíritu Santo); four accidents involving one fatality in SERAC 4; and two accidents involving three fatalities in SERAC 5 (the states of Paraná, Santa Catarina and Rio Grande do Sul).

Rocky said that many factors are responsible for Brazil's trend of decreasing civil aircraft accidents, including an educational system that has certified more than 4,000 aviation safety specialists, use of independent safety audits, involvement in global aviation safety efforts and the use of risk analysis to improve safety in the context of rapid growth.

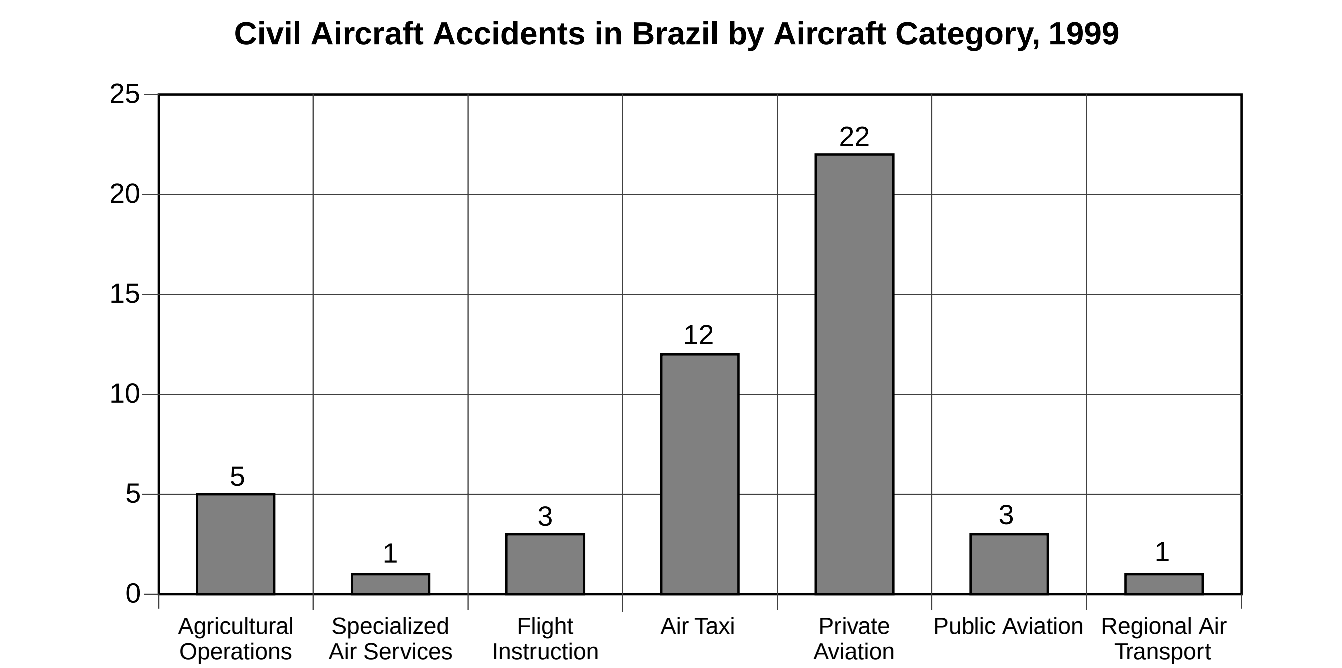
The region's countries comply with ICAO Annex 13 accident-investigation requirements, he said, but typically do not release any facts prior to a final accident report, which often occurs three years after an accident.

"My position is that if you release such information, you already are preventing the next accident," said Rocky. "Data about aircraft accidents and incidents have been terribly hard to get. Everything is kept by the governments. The best way to improve the exchange of safety information is a process like the IATA SAC, where we exchange safety information among airlines in a confidential environment. This also is happening in the Miami RCG, but we need to share information more widely."



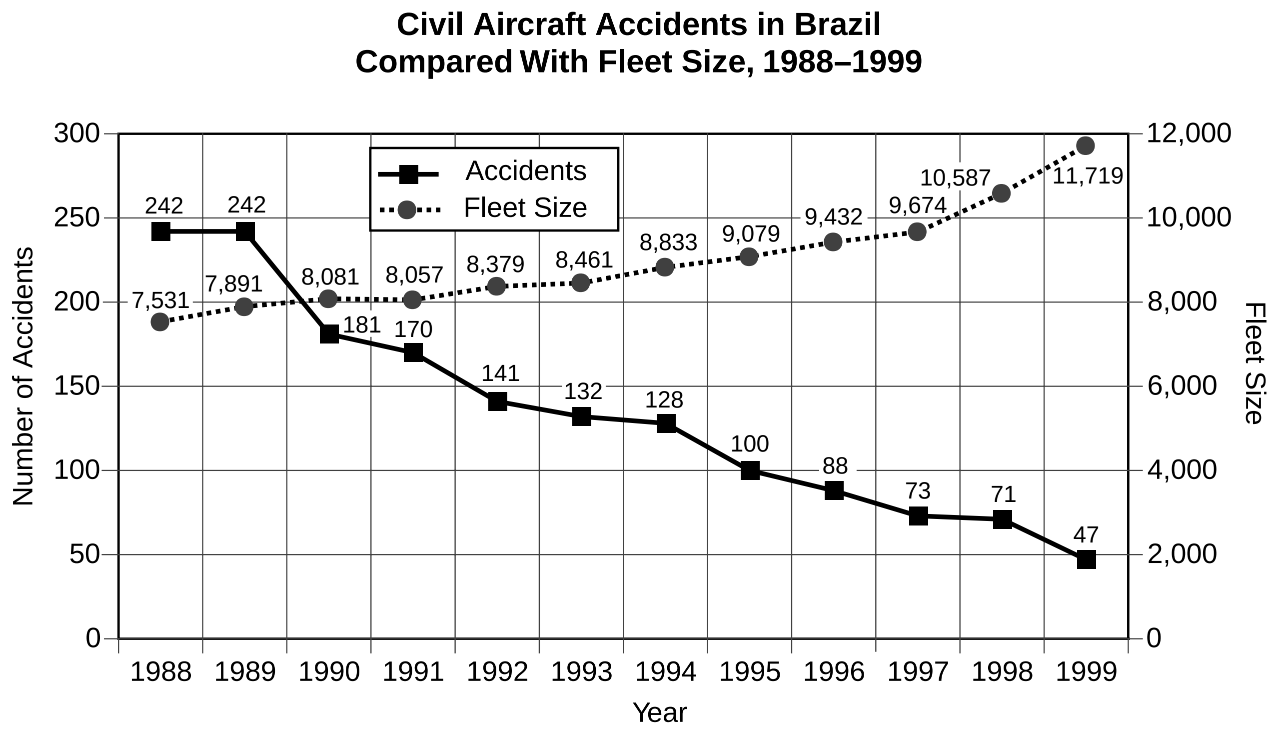
Source: Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA), Brazil Center for Investigation and Prevention of Aeronautical Accidents (CENIPA)

Figure 2



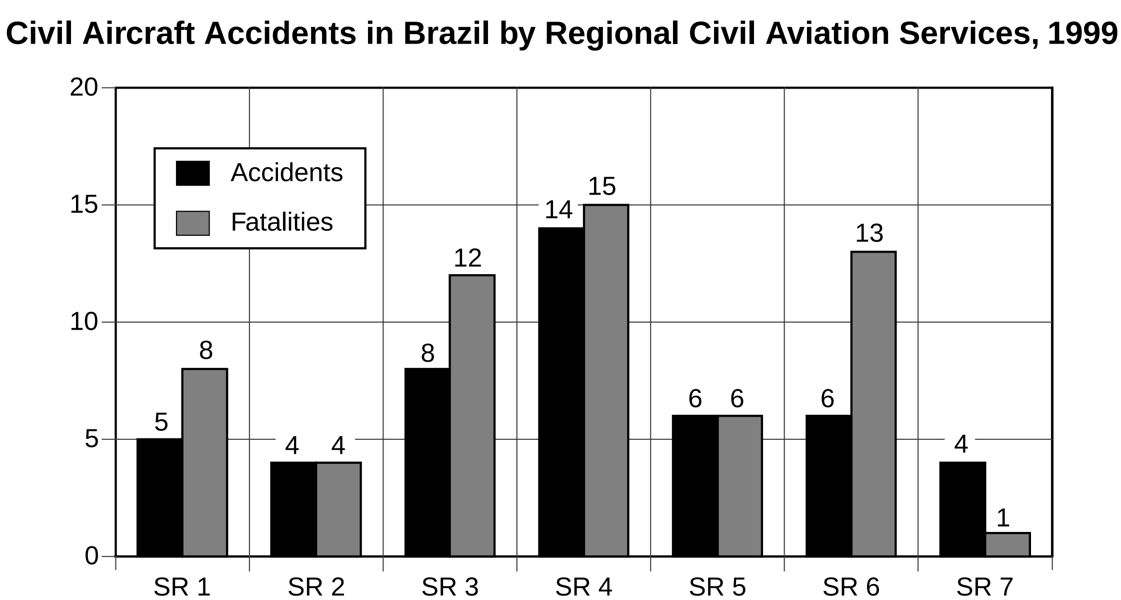
Source: Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA)

Figure 3



Source: Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA)

Figure 4



SR = Regional Civil Aviation Service (SERAC)

SERACs comprise the following states of Brazil: SERAC 1, Pará, Matanhão and Amapá; SERAC 2, Pernambuco, Alagoas, Sergipe, Bahia, Piauí, Fortaleza, Paraíba and Rio Grande do Norte.; SERAC 3, Rio de Janeiro, Minas Gerais and Espíritu Santo; SERAC 4, São Paulo and Mato Grosso do Sul; SERAC 5, Paraná, Santa Catarina and Rio Grande do Sul; SERAC 6, Distrito Federal (Brasilia), Mato Grosso, Goiás and Tocantins; and SERAC 7, Amazonas, Roraima, Acre and Rondônia.

Source: Brazil Civil Aviation Department (DAC), Investigation and Prevention of Aircraft Accidents Division (DIPAA)

Figure 5

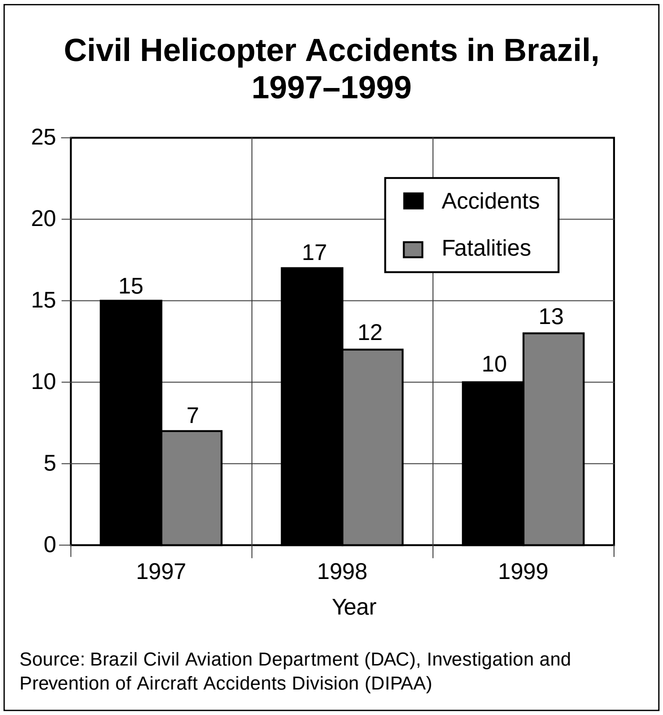


Figure 6

Efforts to organize PAAST began at a July 1998 meeting in Buenos Aires, Argentina, attended by aviation safety specialists from IATA, ICAO, the Latin American International Air Transport Association (AITAL), the Foundation, the International Federation of Air Line Pilots' Associations (IFALPA) and airlines, manufacturers and regulators. Rocky said that they reached a consensus on the following initial agenda, recognizing that the priority order will vary by nation: controlled flight into terrain (CFIT); approach-and-landing accidents (ALAs); rejected takeoffs; engine-out training; dangerous goods and cargo; ground-proximity warning systems (GPWS) and terrain awareness and warning systems (TAWS); traffic-alert and collision avoidance systems (TCAS); emergency-response capability; airport audits; safety audits of operators; exchange of safety information; and development of a regional accident/incident database. PAAST has been designing a two-year work process and an implementation plan to reduce hull losses in this region by 50 percent by 2004.

"Our concept is a common agenda with the Commercial Aviation Safety Team [CAST, a collaborative industry-government organization in the United States] and the Flight Safety Foundation," Rocky said. "I have proposed a strong connection between PAAST and CAST for mutual benefit. I also believe that we should be providing data directly to the FSF Approach-and-landing Accident Reduction (ALAR) Task Force because they have more resources to analyze this region's data. But since we have different problems, we should adopt the agenda to our scenarios. Despite limited data, PAAST members know better than anyone what is happening here, what is needed and the idiosyncrasies and details of each nation. The most important aspects are to integrate everyone, to look in the same direction, to speed up the PAAST process and to maintain interest in the work."

Rocky gave the following examples of the challenges involved in meeting diverse needs of different nations in the Latin America and Caribbean region:

- A major issue for the PAAST steering committee has been the exchange of safety information in the region. "Regulators typically are part of the military, so there is a strong tendency to guard information and not to release information," he said. "Legal liability also is a very big concern";

- In three countries, the laws do not require an airline to have a safety officer, a safety department or a formal safety program, he said;

- The major concern of the aviation community in Ecuador has been CFIT accidents and ALAs, he said, while some of the other issues have been less important;

- "CFIT is on the PAAST agenda, in part, because we have big mountain ranges," said Rocky. "In approach-and-landing accidents we have seen a tendency to fly rushed approaches. This can result in a tendency to abandon formal procedures. As soon as the crew acquires a visual reference, they go visual (conduct landings without maintaining constant reference to the instrument indications). We still have lots of ALAs with this scenario";

- "Effective control of dangerous goods and cargo has been almost nonexistent in 90 percent of the region's countries," Rocky said. "There are regulations, but inadequate enforcement. We have good policy and procedures, but don't have good practices." The PAAST steering committee believes that education about dangerous goods has been inadequate and that the complexity of oversight varies among nations, he said. For example, Rocky said that for Chile, controlling dangerous goods and cargo at three international airports is less complex than in Brazil, which has 30 international airports;

- In Argentina, the military government conducts all disaster-response operations, so a goal of more disaster planning has lower priority than some other issues. But formal training for aviation-disaster response must have a high priority in Brazil where, for example, a Fokker 100 aircraft struck terrain soon after takeoff in Sao Paulo in October 1996 and the emergency response by local authorities was essentially the same as for a bus accident or train accident, causing loss of evidence needed for the accident investigation, he said;

- In some nations there is a belief that only military personnel can conduct a safety audit of civilian operators;

- "We continue to see many accidents and incidents involving rejected takeoffs because of crews not following the specified procedures," said Rocky. "In September 1999, an accident with 80 fatalities occurred in Argentina. The accident involved a configuration problem and the takeoff was rejected after the aircraft reached V_1 [U.S. Federal Aviation Regulations define V_1 as the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance and as the minimum speed in the takeoff following a failure of the critical engine at V_{EF} at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance]. We also have seen mishandling of engine problems after an engine-out indication"; and,

- GPWS and TAWS are not widely used in the region. Rocky said, "Less than 15 percent of this region's fleet has GPWS. Few operators — you could count the aircraft on both hands — have enhanced GPWS."

Rocky said that all efforts to improve aviation safety in the region must consider the following factors:

- Geographical factors — such as mountain ranges and vast areas without large airports — remain a significant challenge to navigation and air traffic control in South America. Rocky said that some countries have 100 percent radar coverage of their territory, but one currently lacks any serviceable radar equipment. Less than 10 percent of the region's fleet is equipped with TCAS, he said;

- "It's my belief that the best measure against CFIT in the region is the teaching process," said Rocky. "We should invest more in education. The same solution applies for ALAs. The key is to show people how important CFIT and ALA prevention strategies are;"

- PAAST members will need to educate national regulatory authorities about regional problems and common solutions, he said. Rocky said, "We are regulated by the states, in many cases by military governments, so we must attract government and military representatives to participate in international safety initiatives. We have invited them to participate in PAAST and Brazil, Argentina, Chile and Peru have shown interest";

- He said that the basis of wider regional adoption of GPWS/TAWS, TCAS and other technologies is education of the entire aviation community about new systems, but significant safety improvement begins with training. If crews are trained to prevent CFIT and ALAs, they will operate with a greater safety margin, he said. The PAAST steering committee believes that the issues of GPWS/TAWS, TCAS and dangerous goods and cargo are affected primarily by economic constraints. Rocky believes that government incentives to operators will be required to solve these problems; and,

- "Ideally independent safety audits should be conducted periodically," said Rocky. "Audits were conducted in 1998 and 1999, for example, in Argentina, Cuba and Ecuador under the auspices of the IATA Miami RCG." When IATA was invited by Argentina to conduct the audit — which some nations prefer to call a technical visit — the results reinforced the work of the nation's safety specialists and resulted in improvements. An audit of one airport, for example, showed limited aircraft rescue and firefighting capabilities. An international audit team found that adequate protective clothing for firefighters was not available and as a result, new protective clothing was purchased. In an audit of runways at an airport in Buenos Aires, foreign-object damage (FOD) was identified as a problem. The RCG arranged for a seminar about how to prevent FOD to aircraft. Significant improvements in preventing FOD resulted when airport workers understood the importance of putting garbage in proper receptacles and of maintaining runways, taxiways and ramps in clean condition. Rocky said that audit teams comprising safety specialists of different nationalities have been the key to acceptance of technical visits in the region. "The RCG has airlines meet twice a year, and it's becoming much easier for countries to ask the RCG for a technical visit," said Rocky.

Rocky said that two recent incidents underscore the need for more work on the prevention of ALAs in the region, although he did not have official causal factors. In one incident, an Embraer 145 touched down near the midpoint of the runway in Uberaba, Minas Gerais, Brazil, in late September 1999 and overran the runway without aircraft damage or injuries. In one incident in October 1999, the crew of a Boeing 737-500 conducted an approach to Navegantes, Santa Catarina, Brazil, and the aircraft overran the runway without aircraft damage or injuries, he said.

Rocky said, "In both cases, we believe that unstable approaches were conducted. A land-at-all-costs mentality is involved in many such incidents in the region — even though crew training stresses 'Pilots soon forget a missed approach, but they never forget an accident.' In the last 10 years to 15 years, there has not been a penalty for pilots who conduct a missed approach." Nevertheless, Rocky said that peer pressure and strong personal motivation to land the aircraft have been part of the ingrained aviation culture of the region, and that training is the key to change.

"Within a short period of time, I believe we will see a decline in CFIT and ALAs because of current training that involves the use of approach-safety gates and other improved standard operating procedures," Rocky said. "Almost always in CFIT accidents, for example, you have a loss of situational awareness. Until recently, there was not a standard aviation term in Portuguese for loss of situational awareness." A term has been adopted and incorporated into CFIT/ALA training, however, and pilots throughout Brazil emphasize the concept, acknowledge loss of situational awareness and talk more openly about CFIT/ALA preventive measures, Rocky said.♦

Note

1. The International Civil Aviation Organization (ICAO) map of statistical regions shows that the ICAO Latin America and Caribbean Statistical Region comprises the following nations and territories (ICAO contracting states and noncontracting states are not distinguished):

   - Nations of Antigua and Barbuda; Argentina; Bahamas; Barbados; Belize; Bolivia; Brazil; Chile; Colombia; Costa Rica; Cuba; Dominica; Dominican Republic; Ecuador; El Salvador; Grenada; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Nicaragua; Panama; Paraguay; Peru; St. Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; Uruguay; and Venezuela; and,

   - Martinique, Guadeloupe, St. Martin, St. Barthelemy and French Guiana (territories of France); Aruba, Curaçao, Bonaire, St. Maarten, Saba and St. Eustatius (territories of The Netherlands); Anguilla, Bermuda, British Virgin Islands, Cayman Islands, Montserrat, Turks and Caicos Islands, and Falkland Islands (territories of the United Kingdom); and Puerto Rico and Virgin Islands (territories of the United States). A dispute exists between the government of Argentina and the government of Great Britain and Northern Ireland concerning the sovereignty of the Falkland Islands (Malvinas).

Publications Received at FSF Jerry Lederer Aviation Safety Library

FAA Publishes Guidelines for Operational Approval of Digital Communication Systems

Advisory circular describes acceptable methods for training and maintenance.

FSF Editorial Staff

Advisory Circulars

Initial Air Carrier Operational Approval for Use of Digital Communication Systems. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) No. 120-70. Feb. 17, 2000. 22 pp. Available through GPO.*

This advisory circular (AC) provides an acceptable method — but not the only method — for operational approval to use digital communication systems for air traffic service and related capabilities for operations under U.S. Federal Aviation Regulations Parts 121, 125, 129 and 135. The AC describes the digital communication operational-approval process, acceptable training methods, acceptable maintenance programs, operational policies, appropriate action during an exceptional air traffic control digital communication event and criteria for foreign operator use of digital communication in U.S. airspace. The discussion includes data link and voice communication services. [Adapted from AC.]

Reports

The Effects of Previous Computer Experience on Air Traffic-Selection and Training (AT-SAT) Test Performance. Heil, Michael C.; Agnew, Brandy O. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report No. DOT/FAA/AM-00/12. April 2000. 11 pp. Available through NTIS.**

Keywords:
1. Air Traffic Control Specialist
2. Personnel Selection
3. Computerized Tests
4. Computer Experience

One disadvantage of tests that are administered on a computer workstation is that the tests inadvertently measure extraneous abilities related to experience with a computer keyboard and a mouse. This study used a computerized selection test to examine the relationship between prior use of computers and test performance. Ninety-six people participated in the study, which assessed their computer experience with the Computer Use and Experience Questionnaire and administered the Air Traffic-Selection and Training (AT-SAT) test. Education was most predictive of AT-SAT test scores, but the study also found that people with more computer experience received higher composite AT-SAT scores. The study recommended further research to determine how training could change the relationship between computer experience and test performance to ensure that computer experience would have minimal effect on personnel decisions. [Adapted from Abstract.]

Books

Shaping Air Transport in Asia Pacific. Oum, Tae Hoon; Yu, Chunyan. Aldershot, Hants, England: Ashgate Publishing, 2000. 255 pp.

Economic growth prompted a rapid increase in demand for air travel in the Asia Pacific in the 1980s and 1990s, and demand for air travel in the region was projected to grow by 7.4 percent a year between 1995 and 2010 — twice the rate forecast for the rest of the world. Forecasts said that by 2014, more than half of all air-passenger movement worldwide would involve travel within the Asia Pacific or to and from the Asia Pacific. Economic turmoil in the region, however, prompted a decrease in Asia's wealth and purchasing power, along with a decrease in air travel and lower demand for freight transport. The book assesses the short-term effects and long-term effects of the economic crisis, the outlook for the aviation industry in the Asia Pacific region and options for development of the regulatory system. Contains a bibliography, glossary and index. [Adapted from Preface and inside front cover.]

Handbook of Simulator-Based Training. Farmer, Eric; Van Rooij, John; Riemersma, Johan; Jorna, Peter; Maraal, Jan. Brookfield, Vermont, U.S.: Ashgate Publishing, 1999. 364 pp.

Technology makes possible an increasing amount of training and instruction using training simulators instead of actual systems. Nevertheless, the use of training simulators has not always been successful because of problems with instruction, program development and inadequate simulator specifications. This handbook provides an overview of the European state of the art in simulator-based training and describes a multidisciplinary research project conducted by specialists in human factors, information systems, and system design and engineering from 23 research and industrial organizations in five countries: France, Germany, Netherlands, Spain and the United Kingdom. Project results have been documented and synthesized to provide guidelines and a common frame of reference. Contains a glossary and index. [Adapted from inside front cover.]♦

Sources

*Superintendent of Documents
U.S. Government Printing Office (GPO)
Washington, DC 20042 U.S.

**National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
+1 (703) 487-4600

Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Advisory Circulars

AC No.	Date	Title
90-91E	March 1, 2000	*North American Route Program (NRP)*. (Cancels AC 90-91D, *National Route Program,* dated Aug. 23, 1999.)

International Reference Updates

Airclaims

Supplement No.	Date	
119	March 16, 2000	Updates "Major Loss Record"

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

Amendment No.	Date	
2/00	April 20, 2000	Updates the General, Communications, Meteorology, Rules of the Air and Air Traffic Services, Search and Rescue, Aeronautical Charts and Publications, and Airmanship sections of the A.I.P.

Nosewheel's Separation From Landing Gear Halts Takeoff

The pilots stopped the airplane at the runway threshold after feeling a bump and assuming that a tire had failed.

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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.

Air Carrier

Axle Failure Blamed For Wheel's Separation

Lockheed L-1011. Minor damage. No injuries.

The airplane was being taxied onto the runway for an early afternoon takeoff from an airport in England when the crew felt a bump. The captain believed that a tire had failed, and the crew of a nearby airplane told air traffic control that they observed a problem with the L-1011's nosewheel. The captain stopped the airplane at the runway threshold and shut down the engines. Controllers declared an aircraft ground incident and dispatched ground equipment to help passengers disembark.

Examination of the airplane revealed that the right nosewheel had separated from the nose landing gear because of an axle failure. An inspection revealed that the axle had failed because of multi-origin cracking around the bottom half of the axle's circumference.

The landing gear had accumulated 51,938 flight hours since new and 25,879 flight hours (7,871 flight cycles) since an overhaul in 1990.

Another L-1011 experienced a similar axle failure in 1984. The crew did not realize that a nosewheel had failed, and they completed an otherwise normal flight and normal landing in the airplane.

The manufacturer determined that revisions of the component maintenance manual were needed to prescribe a method of removing the axle sleeve and chrome coating during overhaul to inspect the axle.

Multiple Bird Strikes Damage Engines

Boeing 757. Minor damage. No injuries.

Immediately after rotation, the flight crew observed a large flock of birds flying across the airplane's direction of flight at a U.S. airport. The pilots said later that the birds probably had come from a grassy area next to the runway.

At about 100 feet, the airplane flew into the flock, which consisted of several hundred birds. The captain said that each engine had a "short, instantaneous reaction, much like a compressor stall," but that the engines recovered quickly and appeared to operate normally. The flight crew kept the airplane in the traffic pattern for a return to the departure airport.

The landing was normal, and the airplane was taxied to the gate, where passengers deplaned. Airport personnel estimated that the airplane was struck by between 150 and 200 birds, which caused first-stage fan damage in both engines and minor impact damage to the wings, lift devices, fuselage and landing gear.

Bumpy Landing Damages Lower Aft Fuselage

McDonnell Douglas MD-11. Minor damage. No injuries.

Visual meteorological conditions prevailed for the daytime flight to an airport in England, where the three-member flight crew was to deliver the airplane to a contract maintenance facility.

The captain flew a five-mile (eight-kilometer) final on a visual approach to the runway. As the airplane touched down, the nose pitched up eight degrees to 10 degrees, the captain began a go-around and the crew felt a bump.

The next approach and landing were normal, but maintenance technicians observed damage to the lower aft fuselage, two drain masts and a very-high-frequency antenna — all of which was indicative of a tail strike.

Air Taxi Commuter

Ground Power Unit Fire Prompts Evacuation From Airplane

Jetstream 41. Minor damage. No injuries.

The airplane was taxied to the gate at an airport in England, and the crew completed shutdown checks. A ground power unit (GPU) was positioned near the aircraft's nose, and the connector socket on the GPU lead was inserted into the airplane ground power receptacle.

The GPU was started and emitted what was described as a "normal amount" of black smoke, but then flames were observed around the ground power receptacle on the right side of the airplane's nose.

The captain ordered evacuation of the airplane through exits on the left side as the ground handling engineer shut down the GPU and used the GPU fire extinguisher to extinguish the fire.

Examination of the airplane revealed scorched paint around the ground power receptacle. The connector on the GPU power lead was overheated, and two of the four cables were burned. The organization responsible for maintenance of the GPU had examined the GPU connector the day before the fire and had determined that the connector was fit for service.

Captain Lands Airplane With Jammed Elevator Trim Tab

Cessna 402B. No damage. No injuries.

The captain was preparing the airplane for a mid-morning descent to an airport in Australia and was trimming the elevator when he heard a loud noise. The control wheel moved forward, and the airplane pitched down. The captain stopped the nose-down pitch but could not correct the trim to eliminate nose-down control forces.

After landing, an inspection revealed that the elevator trim tab was stuck in the nose-down position. X-rays showed that threads in the trim-tab screw assemblies were worn. The shaft was bent and jammed in a position that corresponded to the trim tab's nose-down position. Investigators said that the screw assemblies probably had disconnected when the captain turned the elevator trim wheel and that the trim tab then entered a flutter mode that continued until flutter forces bent and jammed the shaft.

The elevator trim actuator assembly is required to be overhauled every 1,000 flight hours, or every three years, whichever is sooner. In this instance, an overhaul was performed 738 flight hours, or two years and four months, before the incident. During the overhaul, one screw assembly was replaced because of wear; the other screw assembly remained in service.

After the incident, the Australian Civil Aviation Safety Authority published an airworthiness advisory circular (AAC1-111) that described the flutter problems that can be associated with inadequate trim-tab maintenance, and the Australian Transport Safety Bureau (formerly known as the Bureau of Air Safety Investigation) recommended that Cessna Aircraft Co. re-code the elevator trim-tab component parts so that they must be purchased as a single unit, rather than as individual parts.

Post-accident Inspection Reveals Improperly Installed Oil-reservoir Filler Cap

De Havilland DHC-6. Substantial damage. Six minor injuries.

The captain conducted a preflight inspection and told line personnel to add engine oil to the oil reservoirs. The pilot said that he then checked the engine-oil-reservoir filler caps and that no one else touched the caps before takeoff.

About two minutes after the mid-morning departure in visual meteorological conditions from an airport in the United States, the right engine-oil-pressure warning light illuminated. The pilot then informed air traffic control of the problem, shut down the right engine, feathered the right propeller and returned to the departure airport. As the pilot flew the airplane on final approach, he heard a radio transmission from another pilot taxiing for takeoff. He continued the approach, with full flaps extended, until the airplane was 1,500 feet (458 meters) from the approach end of the 3,000-foot (915-meter) runway and then began a go-around. The airplane struck terrain as the pilot attempted to maneuver the airplane to land on another runway. The pilot said that, during initial approach, he had not seen the other airplane on the runway.

Subsequent examination of the airplane revealed that the left wing assembly had separated from the rear attach point, that the nose was destroyed and that the nosewheel had separated from the airplane. Oil was observed on the right engine cowling and wing strut. The report said that the oil-reservoir filler cap had not been installed properly.

Corporate
Business

Thrust Reverser Deploys After Crew Shuts Down Engine

Learjet 55. Minor damage. No injuries.

Day visual meteorological conditions prevailed for the flight from an airport in the United States. About 40 minutes after takeoff, as the airplane was being flown at Flight Level 260, the crew heard a loud explosive noise and observed the airplane yaw.

Instruments indicated that the right engine had failed. The crew secured the right engine. As the crew prepared to declare an emergency, the right-engine-thrust-reverser doors deployed, and the airplane yawed "violently" right, the report said. The crew tried to stow the thrust reverser by selecting the "emergency stow" rocker switch, but the thrust-reverser doors remained deployed. The airplane was landed with the thrust reverser deployed, but after touchdown, the thrust-reverser doors retracted.

Examination of the engine revealed a fracture of the stage 2 low-pressure turbine disk. A segment of the disk rim containing eight slots had separated from the disk. The separation occurred about 0.25 inch (0.6 centimeter) inboard of the firtree slot bottoms.

The fracture surface of the separated rim segment displayed a "distinct heavy oxidized thumbnail pattern, with intergranular features indicative of a dwell fatigue fracture mode," the report said. Secondary cracks were observed in the web area of the disk next to the fracture surface, and grain coarsening was observed in the web of the disk next to the fracture surface.

Landing Gear Collapses After Touchdown

Rockwell Commander 690C. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the late-morning flight under an instrument flight rules (IFR) flight plan to an airport in the United States. As the airplane neared the destination airport, the pilot canceled the IFR clearance and entered the traffic pattern on a left-base leg for Runway 24.

Surface winds were from 280 degrees at 26 knots with gusts to 31 knots.

Because of turbulence, the pilot increased approach airspeed by five knots, then made what he called a "normal touchdown, not particularly hard, within the first third of the runway and on the right-main landing gear." The pilot said that the left-main landing gear touched down and that the airplane rolled about 100 feet (31 meters) before the left-main landing gear collapsed and the airplane skidded to the left and stopped partially off the runway.

Witnesses said that the airplane touched down first on the left-main landing gear. One witness reported first seeing smoke and then seeing the landing gear collapse; other witnesses said that the airplane then bounced and touched down on the right-main landing gear before settling on the left propeller and the fuselage.

An inspection of the scene revealed skid marks on the 5,601-foot (1,708-meter) runway beginning about 3,100 feet (946 meters) from the runway threshold, left of the centerline. The marks continued for 1,100 feet (336 meters).

Examination of the airplane revealed that the left-main landing gear inboard retract-cylinder clevis was fractured about one inch (2.5 centimeters) below the attaching bolt hole and that the upper drag brace was cracked in the webbing where the landing gear door-actuating mechanism was attached.

The crack at the center of the upper drag brace progressed through a manufactured hole, and there were small fatigue crack regions on both sides of the hole, the report said. There was no evidence of pre-existing mechanical damage or other defects in the hole.

Proficiency-check Incident Prompts Review of Training Issues

Learjet 35A. Minor damage. No injuries.

The pilot flying (PF) was receiving a six-month proficiency check from a flight instructor at an airport in Australia. The flight instructor's briefing included instructions that, during a simulated engine failure, the airplane should be landed with 20 degrees of flap and at landing-approach speed plus 10 knots.

The instructor took control of the airplane on the downwind leg to simulate a right-engine failure by placing the thrust lever in the idle position. The aircraft drifted to the right. The instructor returned the airplane to balanced flight, and the PF took control of the airplane with the landing gear up and eight degrees of flap. The PF selected 20 degrees of flap during the base-leg turn, and the airplane was flared normally with both thrust levers in the idle position. When the aircraft settled, both pilots experienced vibration and realized that the landing gear was up. The pilots conducted a go-around, and the airplane was flown in the traffic pattern for a normal full-stop landing. Inspection of the airplane revealed abrasion of the lower-fuselage-mounted very-high-frequency blade antenna.

An investigation revealed that the PF was allocated one hour of flight time in a Learjet every three months and that the instructor had planned the flight to give the PF as much time manipulating the controls as possible.

"In doing so, the normal two-crew, challenge-and-response routines were abandoned, and the checks had to be accomplished by the instructor alone," said the report. "The instructor became distracted by the asymmetric handling issues and the demands of the low-level circuit, subsequently forgetting the relevant downwind and pre-landing checks. The handling pilot, who had been absorbed with controlling the aircraft, had lost situational awareness and did not notice the lack of check procedures by the instructor or the lack of a positive gear-down indication."

The approach was conducted with 20 degrees of flap instead of full flap because the operator had experienced partial loss of control during a previous approach and go-around during a simulated engine failure with full flap. With 20 degrees of flap, however, the landing-gear warning system was inhibited.

After the incident, the operator prohibited variations in the normal challenge-response checklist procedures and required that landings during simulated engine failures be conducted in accordance with the flight manual.

Other General Aviation

Tow Plane, Maneuvering Glider Collide Near Gliderport

Cessna 305A; Burkhart Grob G 103 Twin II. Two aircraft destroyed. Three fatalities.

The airplane had just departed, with a glider in tow, from a gliderport in the United States. The accident glider was maneuvering about one mile (1.6 kilometers) from the gliderport. Day visual meteorological conditions prevailed.

The pilot of the glider in tow, who was not injured, told investigators that, as the tow plane climbed through 1,000 feet, he observed the accident glider about 1,500 feet (458 meters) away and about 100 feet above the tow plane.

"It became apparent to me that the flight path of the Grob and the path I was on following the tow plane might cause a collision if no evasive action was taken," the glider pilot said. "I pulled the rope release at about 1,200 feet AGL [above ground level] and turned to the right with about a 45-degree banking turn. … I leveled off and looked off to my left in time to see the Grob and Cessna approach and collide. I do not think that either aircraft was taking evasive action."

He said that the collision occurred about five seconds after he released his glider from the towrope.

The Cessna and the Grob both were equipped with communications radios.

Pilot Fined After Airport Accident

De Havilland 82A Tiger Moth. Substantial damage. Two minor injuries.

The airplane was being flown to an airport in England for a photography session. The pilot said that, on final approach, he misjudged the height of a wheat crop beneath the flight path, and the airplane's main wheels touched the wheat about 30 feet (nine meters) before the runway threshold. The resulting drag caused the airplane to settle onto its nose and left wing.

After a 180-degree turn on the ground, the airplane came to a stop on its side, and the pilot and passenger climbed out.

Investigators said that they were given another explanation for the accident that held that the pilot was flying the airplane on the fifth low pass for a publicity photograph. After the airplane passed grass-cutting equipment, the pilot executed a climbing turn, followed by a descent. When the landing gear touched the wheat, the airplane flipped over.

The pilot subsequently pleaded guilty in court to endangerment and was fined. Aircraft insurers denied the aircraft owner's claim "because of the pilot's deliberate infringements of the law," the report said.

Oleo Strut Collapses After Hard Landing

Piper PA-38-112. Substantial damage. No injuries.

Day visual meteorological conditions prevailed for a student pilot's takeoff-and-landing practice at an airport in England with an instructor in the airplane. During the student's first landing, the airplane touched down "a little heavily," said the instructor.

There was no indication of damage, and the airplane was flown on a second circuit, which ended in a greatly improved touchdown. Nevertheless, when the student lowered the nose of the airplane, the nose-gear leg collapsed, and the nose struck the runway. The aircraft turned to the right and came to a stop.

An inspection revealed that the nose-landing gear oleo strut had broken just above the lower swivel journal. Metallurgical examination revealed that the oleo cylinder had failed because of a high-load application that worsened an existing fatigue crack that had propagated from the cylinder bore. A similar accident, also blamed on fatigue cracking of the oleo-strut bore, had been reported two months earlier in Scotland.

After the second accident, the U.K. Air Accidents Investigation Branch reiterated its recommendations that the manufacturer revise the maintenance manual to clarify procedures to be used in inspecting the cylinders and that the U.S. Federal Aviation Administration, working with the manufacturer, should devise an in-service inspection procedure to identify fatigue cracks in the oleo strut bore or to specify a service life for the strut cylinders.

Rotorcraft

Engine Cowlings Detach During Flight

Aerospatiale SA342 Gazelle. Minor damage. No injuries.

The helicopter was being flown into the traffic pattern for an afternoon landing at an airport in England. When the pilot began a turn onto the downwind leg at 150 feet, he heard a bang and felt vibration through the airframe. As the severity of the vibration lessened, the pilot heard another bang. He then declared "pan pan" (the terminology for a transmission to inform air traffic control of an aircraft in an urgency condition) and landed the helicopter on the grass near a taxiway.

Inspection of the helicopter revealed that all three main-rotor blades had experienced superficial damage and that both engine cowlings were missing. One cowling was found on the runway; the other was found near the runway. The pilot said that the forward locking device for the cowlings had failed.

Pilot Blames 'Bad Technique' For Accident

Robinson R44. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the sales-demonstration flight from an airport in the United States. As the pilot was preparing to land the helicopter in early evening, the aircraft bounced one inch to two inches (2.5 centimeters to five centimeters). The pilot said that he applied right cyclic and that the main rotor struck the ground and the tail boom. Then the helicopter's nose pivoted 180 degrees, and the tail boom was severed.

The pilot told investigators that he considered the accident a result of "bad technique."♦

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