NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT ACCIDENT REPORT

UNITED AIR LINES, INC.

Boeing 737, N9031U

Chicago-Midway Airport

Chicago, Illinois

December 8, 1972

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-AAR-73-16

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SYNOPSIS

A United Air Lines Boeing 737-222 crashed on December 8, 1972, at 1428 c.s.t. while making a nonprecision instrument approach to Runway 31L at the Chicago-Midway Airport, Chicago, Illinois. The accident occurred in a residential area approximately 1.5 miles southeast of the approach end of Runway 31L. The aircraft was destroyed by impact and subsequent fire. A number of houses and other structures in the impact area were also destroyed.

There were 55 passengers and 6 crewmembers aboard the aircraft. Forty passengers and three crewmembers were killed. Two persons on the ground also received fatal injuries.

The aircraft was observed descending below the overcast in a nose-high attitude and with the sound of high engine power just before it crashed into structures on the ground.

The National Transportation Safety Board determines that the probable cause of this accident was the captain's failure to exercise positive flight management during the execution of a nonprecision approach, which culminated in a critical deterioration of airspeed into the stall regime where level flight could no longer be maintained.

As a result of this accident the Safety Board again emphasized the unique demands for crew coordination and constant vigilance during non-precision approaches. The Board also made several safety recommendations to the Federal Aviation Administration dealing with the use of flight spoilers and the occupant survival and evacuation aspects of this accident.

1. INVESTIGATION

1.1 History of the Flight

United Air Lines Boeing 737-222, N9031U, operating as Flight 553 (UA-553) on December 8, 1972, was a scheduled passenger flight from Washington National Airport, Washington, D. C., to Omaha, Nebraska, with an intermediate stop at the Chicago-Midway Airport, Chicago, Illinois. There were 55 passengers, including 5 children and 2 infants, and a crew of 6 aboard the aircraft.

UA-553 departed Washington at 1250 [1/] on an Instrument Flight Rules (IFR) clearance and was assigned an en route altitude of 28,000 feet by Air Traffic Control (ATC). The flight proceeded in accordance with its IFR flight plan. After its arrival in the Chicago Air Route Traffic Control Center area, UA-553 was cleared to descend to 4,000 feet and was given radar vectors to intercept the Midway Airport Runway 31L localizer course. At 1419, Chicago Center effected a radar handoff and transfer of the flight to Chicago Approach Control.[2/] After contacting approach control, UA-553 was advised that radar contact had been established. The flight was also advised to maintain a heading of 290° and to intercept the Runway 31L localizer course.

At the same time, approach control was handling other traffic, including Aero Commander N309VS which had executed a missed approach at Midway and was being vectored back to the Kedzie outer marker (OM) to intercept the localizer for a second approach to Runway 31L.

Approach control requested UA-553 to decrease airspeed to 180 knots at 1421:56, and to slow to 160 knots 80 seconds later. A clearance to descend to 2,000 feet was issued at 1423:42. Shortly thereafter, the separation between UA-553 and the preceding Aero Commander prompted the controller to request UA-553 to begin slowing to its approach speed. All these advisories were acknowledged by the flight.

At 1424:10, the controller advised the Aero Commander to turn inbound to intercept the localizer and cleared it for the approach to Runway 31L. At 1424:45, the Aero Commander was switched to the Midway Tower frequency with a request to, "... keep up as much speed as long as you can." According to the approach controller, the spacing between the Aero Commander and UA-553 was approximately 3½ miles at that time. At 1424:51, when the Aero Commander reported passing the OM, it was cleared to land on Runway 31L and requested to report when the runway was in sight.

1/ All times herein are central standard, based on the 24-hour clock.

2/ The Terminal Radar Approach Control Facility (TRACON) is located at Chicago-O'Hare International Airport. This facility provides radar approach control service for the Chicago metropolitan area.

At 1425:35, when UA-553 was approximately 2 miles outside the OM and on the localizer course for Runway 31L (as observed on the approach control radar), the flight contacted the Midway Tower and reported that it was out of 3,000 feet for 2,000 feet. After requesting the flight to report passing the OM inbound, the tower controller advised UA-553 that it was number two on the approach. At 1426:30, UA-553 reported passing the OM inbound and was advised by the tower, "United five five three continue inbound. You're number two on the approach. I'll keep you advised."

At 1426:41, the Aero Commander reported the runway in sight and received clearance to land on Runway 31L. About 9 seconds later, the tower controller considered having the Aero Commander land on Runway 31R instead; but when he saw its proximity to Runway 31L, he reissued the clearance to land on that runway. At 1427:04, UA-553 was issued a missed approach clearance as follows: "United five fifty-three execute a missed approach, make a left turn to a heading of one eight zero climb to two thousand." UA-553 replied, "Okay left turn to one eight zero .... left turn Okay." At 1427:36, the controller advised, "United five five three contact departure control now one one eight point four." UA-553 did not acknowledge that transmission; there were no further communications with the flight.

The approach controller stated that after the tower controller had coordinated with him regarding the missed approach clearance issued to UA-553, he noticed that the radar target associated with the aircraft had drifted approximately 1/8 to 1/4 mile to the right of the localizer centerline. He observed the target for two sweeps of the radar antenna after which he saw it disappear from the radarscope.

According to cockpit voice recorder (CVR) information, the captain called for the final descent check at 1426:24, about 4 seconds after the sound of the Kedzie OM identifier ended. The checklist was completed at 1427:03; about 1 second later the first officer called, "Ah, thousand feet." Less than 2 seconds after this call, the sound of stickshaker activation (a device designed to alert the pilot to approaching stall) could be heard on the CVR tape and remained audible until the recording ended at 1427:25. The beginning of the stickshaker sound coincided with the word "execute" in the tower controller's missed approach clearance.

According to surviving passengers, the last public address announcement from the cockpit, made about 5 minutes before impact, indicated that the flight was over Gary, Indiana, at 4,000 feet, and would be landing in about 5 minutes. Some survivors stated that the engine noise decreased at the time the announcement was made, and that this lower noise level remained constant until shortly before impact. Most survivors agreed that there was a rapid application of power just before impact, accompanied by the rotation of the aircraft to a nose-high attitude. The sound level of the engines at this time was described in terms such as "full throttle" and "sounded like on takeoff." One passenger stated that the aircraft "seemed to jerk as the engines came on." Two of the three surviving cabin attendants and one ground witness were of the opinion that there was more than one power "surge."

Several survivors said that the aircraft shuddered following the nose-up pitch change; four of them estimated that the aircraft's nose rose at least 30°. One passenger stated that the nose pitchup occurred in two phases: the first, gradual and to a moderate angle; the second, abrupt and to a high angle.

Several eyewitnesses heard loud engine sounds and observed the aircraft in a nose-high attitude. A licensed pilot stated that when he saw the aircraft break out of the overcast at 400 to 450 feet above the ground, it was descending in a level attitude. He said: "There was a surge of power and there was an abrupt attitude change in the aircraft. The nose went to a very high angle of attack."

The geographic coordinates of the crash site were $41^{\circ}45'51''$ N. $87^{\circ}42'54''$ W.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	3	40	2
Nonfatal	1	15	2
None	2	0	

Two occupants of a house struck by the aircraft received fatal injuries. Two other persons near the accident site received minor injuries.

Post-mortem examinations of the flightcrew disclosed no evidence of incapacitating disease. However, the coroner's autopsy report on the captain included the statement that ". . . stenosing coronary atherosclerosis with ultra-acute focal myocardial infarction . . ." was in evidence. This finding was based on the Hematoxylin-Basic Fuchsin-Picric (HBFP) acid stain technique.

Specimens of the captain's heart tissues subsequently examined by a medical specialist of the Armed Forces Institute of Pathology revealed no evidence of any ultra-acute myocardial infarction. According to one of the developers of the HBFP technique, the method cannot be considered diagnostic of myocardial infarction; in addition, exposure of a victim to carbon monoxide can produce a false positive indication of a myocardial infarction.

1.3 Damage to Aircraft

The aircraft was destroyed by impact and postcrash fire.

1.4 Other Damage

The impact and subsequent fire destroyed five wood and brick frame houses and one garage, and damaged three other houses and two garages. (See Appendix D for detailed information.)

1.5 Crew Information

The captain, first officer, second officer, and flight attendants were qualified and certificated for the operation involved. (For detailed information see Appendix B.)

1.6 Aircraft Information

Aircraft N9031U, a Boeing 737-222, was registered to United Air Lines, Inc. It was certificated, maintained, and equipped in accordance with Federal Aviation Administration (FAA) regulations.

The aircraft weight and center of gravity (c.g.) at the time of the accident, computed to have been 86,394 pounds, and 19.0 percent mean aerodynamic chord (MAC), respectively, were both within specified limits. (For detailed information, see Appendix C.)

1.7 Meteorological Information

National Weather Service surface weather charts showed a relatively ill-defined low pressure area centered approximately 120 miles south of Midway Airport at the time of the accident. That system, coupled with a quasi-stationary front oriented in an east-northeast/west-southwest direction from Virginia to Arkansas, was producing an extensive area of light freezing drizzle, or light freezing rain, and very light snow over northern Illinois.

The following are selected surface weather observations at Midway Airport at the times indicated:

1300 - Record Special, measured 500 feet overcast, visibility 1 mile, fog, temperature 27° F., dew point 26° F., wind 170° 4 knots, altimeter setting 30.04 inches, ceiling ragged.

1400 - measured 500 feet overcast, visibility 1 mile, fog, temperature 27° F., dew point 26° F., wind 260° 6 knots, altimeter setting 30.05 inches, ceiling ragged.

1433 - local, measured 500 feet variable overcast, visibility 1 mile, fog, wind 250° 6 knots, altimeter setting 30.05 inches, ceiling 400 feet variable to 600 feet, aircraft mishap.

The Midway low level radiosonde (upper air) observation made at 1106 showed saturated conditions from just above the surface to approximately

6,100 feet mean sea level (m.s.l.). The air was generally stable with several inversions in evidence. Temperatures were subfreezing except in a layer between about 5,700 and 6,700 feet where temperatures were a fraction of a degree above freezing.

The terminal forecast for Midway prepared by the National Weather Service was: ceiling 500 feet overcast, visibility 1 mile, light freezing drizzle, light snow, fog, variable to ceiling 200 feet obscured, visibility 1/2 mile, light freezing drizzle, fog, or light snow, fog.

Weather Service forecasts for the route included SIGMETS [3] warning of moderate or greater turbulence below 15,000 feet, and moderate to occasionally severe icing in clouds and precipitation. Company forecasts anticipated low level clear air turbulence produced by wind shear at various terminals, including Midway, and also warned of light freezing precipitation.

With his other dispatch documents, the captain of Flight 553 received a weather packet containing current and forecast en route and terminal weather conditions, and forecast winds and temperatures aloft. Similar information was available in the company dispatch office at Washington National Airport.

Several pilots who had made a localizer approach to Runway 31L at Midway just before, and immediately after, the accident were questioned concerning the weather conditions at the time. The pilot of Aero Commander N309VS stated that icing was not an operational problem either during his flight from Indianapolis, Indiana, to Midway, that afternoon, or during his initial approach, missed approach, and second approach to Runway 31L. He added that at no time did he think it was necessary to actuate the wing and empennage deicer boots, although occasionally he applied windshield alcohol because of light rime ice. A post-flight inspection revealed no ice on his aircraft. At minimum descent altitude (MDA) on his first approach, he was "running in and out" of clouds, with "occasional holes;" during his second approach he had better ground visibility at MDA, and he had no difficulty landing. He estimated the ceiling over the airport to have been 500 feet or more, with a visibility of 1 to 1½ miles.

The captain of Delta Air Lines Flight 567, a DC-9 which arrived from Detroit, Michigan, and landed on 31L just before the Aero Commander, stated that he encountered light icing conditions and used all available anti-icing equipment, including empennage anti-icing. He noted very little accumulation of ice on his aircraft, possibly less than a quarter of an inch, during the entire approach. He stated that he was still in the overcast when he was over the Kedzie OM. Just beyond Kedzie, he found some holes in the overcast "and had ground contact right away, but ... didn't actually come out from under the overcast until just about 500 feet."

3/ SIGMET. An advisory concerning weather of such severity as to be potentially hazardous to all categories of aircraft.

The pilot of a Cessna 310, which landed on 31L immediately after the accident, reported that he entered the overcast in the Midway area at 4,000 feet m.s.l. and that he remained in it for about 8 or 9 minutes during his approach. He stated that the buildup of ice on his aircraft was about 1/2 inch and that he intermittently operated the wing and empennage deicing boots. He estimated that he had visual ground contact from an altitude of 500 to 600 feet above the ground.

The accident occurred during daylight hours.

1.8 Aids to Navigation

The localizer approach to Runway 31L at Midway incorporates a localizer, operating on a frequency of 109.9 MHz with an inbound course of 312°, a compass locator (Kedzie) installed at the OM site located 3.3 nmi from the end of the runway, and a middle marker (MM) located 0.6 nmi from the runway. The published procedure shows a minimum crossing altitude over the OM of 1,500 feet m.s.l. (889 feet a.g.l.), at which point descent to the MDA of 1,040 feet m.s.l. (429 feet a.g.l.) is authorized. The missed approach procedure prescribes a climbing left turn to 2,600 feet m.s.l., and thence to proceed to the Peotone (EON) VOR via the 001° radial. The published landing minimums for this approach were MDA 1,040 feet m.s.l. and 1-mile visibility. Also shown on the approach chart is the Calumet intersection, 6.9 nmi from Kedzie, which is formed by the intersection of the 356° radial from the Chicago Heights (CGT) VOR and the runway 31L localizer course. (See Appendix E.)

All navigational facilities (NAVAID's) associated with this approach procedure were flight-tested by the FAA immediately after the accident and were found to be operating within prescribed tolerances. None of the flights using the localizer before or after the accident reported any problems.

1.9 Communications

No discrepancies with air-ground communications between UA-553 and Air Traffic Control (ATC) facilities were reported.

1.10 Aerodrome and Ground Facilities

Runway 31L at Midway Airport is asphalt surfaced and is 6,519 feet long by 150 feet wide. The elevation at the runway threshold is 611 feet m.s.l.; the published field elevation is 619 feet m.s.l. The runway is equipped with high-intensity runway lights, runway end identifier lights, and visual approach slope indicator (VASI) lights, all of which were on and operating at the time of the accident.

Runway 31R, parallel to and approximately 700 feet to the right of Runway 31L, is 5,388 feet long by 150 feet wide and is restricted from use by jet traffic.

1.11 Flight Recorders

N9031U was equipped with a Fairchild Model F-5424 Flight Data Recorder (FDR) serial No. 5134. The altitude, indicated airspeed, magnetic heading, and vertical acceleration traces ended abruptly 82:14 minutes after takeoff (approximately 14 minutes before the accident). Measurements at the end of these traces indicated an altitude of 10,625 feet m.s.l., an airspeed of 307 knots, and a heading of 274° magnetic. Examination of the flight recorder showed that a miter gear (P/N 10466), which is part of the drive gear assembly, had slipped on its shaft causing the recorder to stop functioning.

The aircraft was also equipped with a Sundstrand, United Control Data Division Model V-557, Cockpit Voice Recorder (CVR) serial No. 1648. Although the CVR showed evidence of extreme fire and heat damage, the entire tape was recovered with only moderate damage to a nonpertinent area. A transcription was made of the final 27½ minutes of the recording. Communications and conversations by the individual crewmembers were identified by persons who were familiar with their voices. Simulator studies and aircraft test flights were conducted to duplicate and to record various CVR sounds, such as: gear and flap lever movements, various switch actuations, aural warning signals, etc. A transcript of all pertinent sounds and communications during the last 8 minutes of recorder operations is included in Appendix F.

Precise timing of the CVR data was made by determining the accuracy of elapsed times between recorded events. First, a time base for the CVR recording was established by comparing the recorded identification signal frequency of the Kedzie OM with the known frequency characteristics of that signal. Next, the times thus established for all recorded events were correlated to real time by reference to a recorded time signal that had been transmitted by Aeronautical Radio, Incorporated (ARINC) at 1400.

Comparison of the resulting CVR transcript times with times of identical events recorded by ATC sources showed variances; however, the times were generally within 3 seconds of one another, and there were no differences exceeding 6 seconds.

The cockpit area microphone (CAM) track of the CVR was examined to the fullest extent of the Safety Board's audio laboratory capability in an attempt to identify engine sound frequencies during the final phase of the flight. No evidence relating to engine thrust settings was found. A similar attempt was made by United Air Lines, using special engine-analysing equipment; the results were negative. The CAM track recording was then examined by the General Electric Company's Research and Development Laboratories. The engine operating data developed by General Electric are summarized in Section 1.15, Tests and Research.

1.12 Aircraft Wreckage

The aircraft crashed into a residential area approximately 1½ miles short of the runway and 1/4 mile to the right of the localizer approach course. The main wreckage area, oriented on a magnetic heading of 338°, was approximately 250 feet long and 90 feet wide. The aircraft was in a nearly wings level, nose-high attitude when it first penetrated the uppermost branches of a 20-foot tree. After this contact, the aircraft impacted trees, houses, utility pole cables, and garages before it came to rest across the foundation of one of the destroyed houses. The descent angle, from initial tree contact to the final impact site, was approximately 4.5°. Terrain elevation in the wreckage area is 615 feet m.s.l. (See Appendix D for details.)

Portions of both wings and the fuselage from just aft of the cockpit to the rear galley door were consumed by the postcrash fire. The relatively intact left cockpit section and empennage incurred only minor fire damage. All airframe structural components were accounted for either in the main wreckage area or along the path of impact.

Ground fire damage precluded any determination of the preimpact integrity of the control system or the degree of deflection of the primary flight controls. The horizontal stabilizer jackscrew was found extended to 14½ inches, which corresponded to a stabilizer trim position indication of 9½ units (UAL Stabilizer Trim Scale) aircraft noseup.

The left main landing gear was found almost fully retracted but not completely within the up-lock. The right main gear was completely separated from the aircraft. The nose gear was torn loose from its mount; the position of its retract mechanism indicated that it had been retracted at impact.

Measurement of the landing flap jackscrew actuators showed that the flaps had been extended 37° at impact. (Full flap extension is 40°.) Three of the six wing leading-edge slat actuators were recovered; they were in the extended position. All ground and flight spoiler actuators were found to have been in the spoiler retracted (stowed) position at impact.

The left wing anti-ice valve was found in the closed (wing heat off) position. Damage to the right wing anti-ice valve precluded a determination of its preimpact position. Both air conditioning pack valves were found in the closed position.

Both engines were separated from the aircraft. All first stage fan blades of the No. 1 engine were broken off above the blade root platforms. Nearly all second stage fan blades and all attached fourth stage compressor blades were bent opposite to the direction of compressor rotation. Large amounts of debris and building materials were found in the air inlet and front fan areas of the No. 2 engine. The leading edges of the first and second stage fan blades were extensively damaged and bent opposite to the direction of compressor rotation. Both thrust reversers were in the stowed position.

Disassembly and inspection of compressor, combustion, and turbine sections of both engines showed extensive rotational damage to the fan/compressor blades through the 13th stage. Silver colored metallic deposits were found adhering to the exterior surfaces of the combustion chamber domes, the inner and outer outlet ducts, and all four stages of the turbine blades and vanes.

Inspection of the engine bleed-air systems revealed vegetation or debris in the entrance elbows of the eighth stage bleed-air manifolds and check valves, downstream (eighth stage manifold side) of the pressure modulating valves in the 13th stage bleed-air manifolds, and on the downstream face of the pressure modulation valve butterfly. No debris was found upstream (on the 13th stage side) of the pressure modulating valves or on the upstream face of the modulating valve butterfly. All bleed-air inlet guide vane anti-ice and nose cowl anti-ice valves were open.

The relatively intact, captain's side of the cockpit was damaged by ground fire. The first officer's station, including the instrument panel, was destroyed.

The center control pedestal was torn away at impact from its normal position. The flap selector handle was relatively intact and moved freely between the 30° and 40° positions. The flight spoiler (speed brake) handle was in the stowed position. The stabilizer trim indicator was found set at 9½ units aircraft noseup. The landing gear handle was not recovered.

The No. 1 engine pressure ratio (EPR) gauge was recovered with the pointer indicating 1.66 EPR and with a target EPR reading of 1.97 in the selector window. The No. 2 engine EPR pointer indicated 1.90 EPR with a reading of 1.95 in the selector window.

The anti-ice switches of both engines, the Pitot heat switches, and the window heat switches were "ON." The filaments in the related indicator light bulbs were stretched.

The two VHF navigation receiver frequency selector heads were found set at the Runway 31L localizer frequency.

A functional test of the captain's Attitude Director Indicator (ADI) showed it to be operational in all modes except "go-around." Further examination disclosed that the command bars would not function in this mode because of ground fire damage to the related parts.

A test of the captain's airspeed indicator showed that it was operating within operational specifications, except in the range between 70 and 140 knots, where it read .5 to 5 knots slow.

The No. 1 Horizontal Situation Indicator (HSI) course selector was found set at 317°. All warning flags were in view. The No. 1 Radio Magnetic Indicator (RMI) was recovered; the No. 1 needle indicated a bearing of 178° and the No. 2 needle, a bearing of 133°. The compass card indicated a heading of 351°. The mode selector was positioned to "ADF."

The captain's flight director panel mode selector switch was in the "manual" position. The first officer's mode selector switch was "OFF." The autopilot switches were "OFF."

The captain's and the first officer's altimeters were recovered with barometric settings of 30.05 and 30.04, respectively; no meaningful altitude indications were obtained from either instrument's face. The captain's altimeter appeared to be virtually intact, but showed evidence of ground fire damage. In a functional test, this altimeter responded to pressure changes in the "barometric mode," but because of heat damage to the internal components, no assessment could be made of the preimpact accuracy or operating capability of the instrument in the "servo mode." Only the charred face and a portion of the servo unit of the first officer's altimeter were recovered.

Information concerning the captain's and first officer's air data computers is contained in Section 1.15, Tests and Research.

1.13 Fire

None of the eyewitnesses near the scene of the accident reported seeing fire while the aircraft was in flight, or hearing sounds other than those associated with engine operation. The investigation revealed no evidence of in-flight fire, or of structural damage not related to impact and ground fire.

The first witnesses at the crash site stated that structures on both sides of the aircraft fuselage were burning, and that white smoke was emanating from the fire. They also stated that the fire was very intense around the center section of the aircraft, and that thick black smoke obscured part of the fuselage. The overall conflagration involved the aircraft as well as the destroyed dwellings and their contents.

The Chicago Fire Department was first notified of the crash at 1429. Five engines, three truck companies, one helicopter, one dry chemical unit, and three ambulances responded immediately. The first radio calls reporting that units were "on the scene" were made at 1431 and 1432. Additional alarms were struck at 1437 and 1449.

The fire was put out almost entirely with water; 20 gallons of foam were used in the rear service door area. The main fire was controlled within 20 to 30 minutes after the fire fighting equipment arrived at the scene. Smoke, heat, and small "flareups" continued for more than 3 hours after the crash.

1.14 Survival Aspects

The first sounds of impact were recorded about 1 second before the end of the CVR recording. The aircraft either damaged or destroyed several houses before coming to rest across the foundation of one of them. Except for the aft portion of the coach section, the empennage, and the left side of the cockpit, the fuselage was destroyed by impact and fire. Therefore, the analysis of the conditions in the cabin and the related survival aspects, immediately after impact, is based on survivor observations.

The only survivor in the fuselage section forward of the wing was the first-class flight attendant who occupied the aft-facing jumpseat adjacent to the left forward entry door. She was seriously injured when her seat collapsed and she was trapped by debris from the aircraft and the house. She was freed from the wreckage after an intensive 30-minute rescue operation by Chicago Fire Department personnel. No first-class section seats were recovered intact.

There were 17 survivors in the coach section, including the 2 uninjured flight attendants who occupied the jumpseat in the rear of the cabin. According to the survivors, ceiling panels and hat racks with their contents fell on the passengers and in the aisle of the coach section during the impact sequence; seats dislodged from approximately row 12 to 15, as well as other debris, obstructed the aisle. A survivor who was seated in the center cabin section reported that there was no floor structure under his seat. He released his seatbelt and exited through the cargo compartment and a break in the fuselage. Another survivor stated that he "had the feeling that there were people moving underneath" him as he tried to find an exit. A female survivor reported that "people were scrambling over the seat tops and I was kicked and my hand was stepped on."

Survivors reported that all cabin lights went out after the impact, and that no lights were visible during the evacuation. Six survivors escaped through breaks in the fuselage. Nine passengers who exited through the rear service door were assisted by the two flight attendants; these attendants were the last to leave the aircraft.

The left side of the cockpit and the left forward entry door area were relatively intact. The captain's seat was intact and sustained only minor fire damage. The floor attachments for this seat were in place; the 4-point seatbelt and shoulder harness release mechanism was found unlocked and operable. Shoulder harness straps were found retracted in the inertial reel without signs of scorching or discoloration.

The first and second officers' seats were destroyed by impact and fire. The first officer's shoulder harness straps were found retracted inside the inertial reel and showed no thermal damage.

Injuries sustained by the survivors included fractures of the vertebrae, pelvis, and extremities, as well as first-degree burns. Lack of specific data regarding the injuries sustained by nonsurviving passengers precluded the determination of impact-associated injury patterns and the effect of injuries on the ability to escape. To the extent that the preimpact seat location of the surviving passengers could be established, no distinct survivability pattern emerged. Elevated carbon monoxide levels were found in 27 percent of the fatalities in the first-class section and 76 percent of the fatalities in the coach section. Elevated hydrogen cyanide levels were found in the captain and in six fatalities in the coach section. Carbon monoxide and hydrogen cyanide are some of the toxic products of the thermal decomposition of such materials as wool, cotton, paper and plastics.* According to expert testimony during the public hearing, a study of carbon monoxide and cyanide in victims of house fires in the City of Detroit showed the presence of cyanide in all victims of carbon monoxide poisoning.

In view of the allegations of foul play which have been injected into the publicity surrounding this accident, the Safety Board finds it necessary to present certain aspects of the trauma experienced by nonsurvivors in more detail than would normally be reported.

Four pathologists from the Cook County Coroner's Office prepared brief gross descriptions of the passenger fatalities and established a cause of death in each case. Although the deaths of most occupants were attributed to burns, some of the causes of death mentioned different forms of trauma, such as "multiple injuries" and "extreme" and "partial body destruction." Several also contained the statement, "associated with carbon monoxide asphyxia;" some of them mentioned cyanide.

The causes of death of the first-class passengers were described with more reference to violent trauma than those of the coach passengers. In the gross body description of one first-class passenger, the pathologist used the phrase, "disruption of head, torso, upper and lower extremities by burns and apparently some explosive force." The cause of death of this person was stated as "extensive burns." In describing the body of a victim who had been seated in the rear of the coach section, the same pathologist used the phrase "severe destruction by blast and flames" and attributed the cause of death to "blast injuries and severe burns, associated with carbon monoxide asphyxia." When Board investigators questioned him about the terminology used in these two protocols, the pathologist emphasized that he had found no evidence of effects typical of an explosive device or charge on either victim, and that he had not intended, in using that terminology, to indicate either the presence or the effects of an explosive blast; he stated that his "was a bad choice of adjectives," and that he had used those terms to describe injuries caused by high-energy impact.

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* I. N. Einhorn, "Physio-Chemical Study of Smoke Emission by Aircraft Materials," Federal Aviation Administration, Department of Transportation, 1972.

Interviews with surviving passengers and cabin attendants by personnel of the Safety Board and the Federal Bureau of Investigation revealed no evidence of abnormal or unusual passenger behavior before the impact. It should be noted that the coach passenger whose cause of death described by the pathologist included the words "blast injuries" was seated two rows ahead of the two uninjured flight attendants and directly ahead of two surviving passengers.

The captain sustained a fractured arm, fractured ribs, and lacerations. The cause of his death was attributed to "smoke inhalation with carbon monoxide asphyxia and blood cyanide accumulation." The observations associated with the captain's heart have already been described in Section 1.2.

The first officer's death was attributed to "injuries multiple extreme with severe burns" and other trauma; the cause of the second officer's death was listed as "extensive burns." The results of the toxicological examinations involving these two crewmembers were negative.

1.15 Tests and Research

1.15.1 Automated Radar Terminal Service Data and Derivation of Flight Profile

A special group was established to study those aspects of the UA-553 flight profile that related to the performance characteristics of the Boeing 737 aircraft. The usual sources of data to reconstruct such a profile are the indicated airspeed and altitude traces recorded by the aircraft's FDR. However, because of a mechanical malfunction of the FDR, the data were not available.

Another source of data useful for flightpath derivation is the FAA Automated Radar Terminal Service (ARTS-III) installed at the Chicago-O'Hare International Airport. The ARTS-III system processes the transponder beacon return from all aircraft within a specified range of the approach control radar site. The raw data from the beacon return consist of azimuth and range referenced to the antenna location, as well as an encoded pressure altitude for aircraft equipped with a Mode 'C' transponder. These raw data are manipulated into positional coordinates which are differentiated with respect to the data receipt time to acquire a ground speed for the target. The positional accuracy of the ARTS-III data acquisition system is limited to approximately $\frac{1}{4}^{\circ}$ in azimuth and 1/16 nmi in range.

The processing equipment also applies a correction, based on the current sea level barometric pressure, to the raw altitude data to produce a mean sea level altitude, resolved to the nearest 100-foot level. The received altitude data, also resolved to 100-foot increments, are generated within the aircraft by an altimetry system and, as such, include those errors which may be inherent within that airborne system. In addition, the two-step resolution to 100-foot levels in itself produces a tolerance of $\pm$ 100 feet to displayed altitude data. The data thus generated are selectively presented on the air traffic controller's video display. In addition to the video display, the raw data and calculated parameters for all received targets are stored on a computer-generated magnetic tape.

UA-553 was tracked by the O'Hare ARTS-III system from a position approximately 55 nmi southeast of the antenna site at a computed altitude of 9,500 feet, to a position 15.9 nmi from the antenna site at a computed altitude of 1,000 feet m.s.l. (380 feet above the ground elevation of the impact site). The latter position was approximately 0.2 nmi from the geographical coordinates of the impact site. Since the ARTS-III system requires a line of sight transmission, the loss of a target will generally occur as a result of line of sight obstruction.

The magnetic tape containing the tracking data of UA-553 was examined to reconstruct the aircraft's flight profile before the crash. Meteorological data, i.e., winds and temperatures were applied to the ARTS-III positional and altitude data to derive calibrated airspeed and vertical velocity as a function of time. Use of the ARTS-III raw positional data to calculate airspeed resulted in an erratic trace because of the aforementioned positional tolerances; therefore, it was necessary to smooth these data. The after-the-fact smoothing technique differed from that used in the ARTS-III ground speed manipulation in that future, as well as past, data points could be considered. The result was an estimate of actual value which did not include the lag inherent in the ARTS-III calculation.

A special test was then conducted to determine the validity of results obtained from such manipulation of the ARTS-III data. The ARTS-III tracking data obtained for another aircraft flying the same track as UA-553 were compared with similar data extracted from the other aircraft's FDR. The airspeed values obtained, using both methods, correlated consistently within 10 knots. Since the FDR altitude is obtained from the same source as the aircraft beacon transponder altitude, it was expected that the altitude values would correlate within the resolution and tolerances inherent in the ARTS-III system. Such correlation was, in fact, verified to be within 100 feet.

The ARTS-III computations for UA-553 indicated that the flight, when first acquired at 9,500 feet m.s.l., was descending to 4,000 feet m.s.l. approximately 1,000 feet per minute (ft/min). The flight remained level at 4,000 feet for approximately 5 minutes and decelerated during approximately the last 3 minutes of this period from an airspeed of 230 knots to about 180 knots. At that time, the final approach descent was initiated with a descent rate of 750 ft/min. About 1½ minutes after the start of this descent, the aircraft had decelerated to 145 knots, and the descent rate had increased to approximately 1,250 ft/min. This descent rate was maintained until the aircraft was over the Kedzie OM where the ARTS-III data showed an altitude of 2,200 feet m.s.l. After a momentary level-off, the descent rate increased to about 1,550 ft/min, which was maintained until the aircraft reached 1,100 feet m.s.l. and level-off was initiated. The airspeed at level-off was approximately 120 knots. Level flight was maintained for 16 seconds before the ARTS-III system lost the aircraft's beacon return.

Logitudinal acceleration and vertical velocity were derived from flight changes in airspeed and altitude, respectively. These data were used to establish the most compatible configuration and thrust combinations for simulation of the flight profile in the UAL B-737 simulator and subsequent flight tests.

For further confirmation of the most probable descent configuration, the CVR transcript was time-correlated to the ARTS-III derived data by alignment of the ARTS-III time base with the air/ground transmission times recorded on the ATC voice tape. The time correlation was further verified to within 3 seconds by comparing the time over the Kedzie OM with the time on the ARTS-III data when the aircraft position corresponded to the positional coordinates of the Kedzie OM. (See Appendix G, Approach Profile derived from ARTS-III and CVR Data.)

1.15.2 General Electric Engine Sound Spectrogram Study

At the Safety Board's request, the General Electric Company conducted a sound spectrographic analysis of the CAM track of the CVR recording to determine the presence of frequencies that might be indicative of engine power settings.

The CVR tape contained a high-level background noise which tended to mask meaningful frequency data. Through special filtering techniques much of the noise was attenuated, and some discrete frequencies corresponding to sound generated by aircraft equipment became evident. Frequencies which were interpreted as characteristic of engine rotation sounds generated by the first and second stage rotors of the low pressure compressor (N_1 blade passing frequencies) were discernible for certain increments of time. The results of the comparison of these frequency values with the characteristics of the Pratt and Whitney JT8D-7 engine by the General Electric Company are summarized as follows:

1. Engine sounds were first detected at 1414:36 which corresponded with a power setting of 56 percent N_1 for both engines.

2. A linear, straight line, gradual deceleration continued until 1416:43 when N_1 was at 52.7 percent.

3. A linear, more gradual deceleration then continued until 1419:36 when N_1 was at 51.2 percent.

4. At this point both engines were accelerated to 63 percent N_1. The speed of 63 percent was achieved at 1419:48 approximately. One engine had a slight overshoot, and the other, a slight undershoot.

5. The speed of 63 percent N_1 was held until 1420:55 when it was reduced to 61.5 percent, with stabilization of both engines at 1421:03.

6. The engine speeds of 61.5 percent were then maintained until 1421:52 when speed was again increased to 63 percent N_1 after a 3-second acceleration time.

7. The 63 percent N_1 speed was continued until approximately 1423:55 when speed was reduced to 59.1 percent after a deceleration time of approximately 5 seconds. The engines appeared to be at slightly different speeds at that time.

8. The engine speeds then decreased slightly in a linear fashion, with the N_1 difference increasing slightly until the final acceleration was noted at 1427:03:35. Just before the acceleration, one engine was at 58.6 percent N_1, and the other, at 57.2 percent N_1.

9. The sounds of both engines were detected during the acceleration; one engine peaked at 72 percent N_1 at 1427:07.95; the other peaked at 79.2 percent N_1 at 1427:09.55.

10. The overall noise level of the tape reached a maximum very shortly after the engines reached their peak speeds, making interpretation difficult. Oscillations were noted but little can be said regarding their nature except that their extremities did not exceed the equivalent of 4 percent N_1.

1.15.3 B-737 Performance Study

The performance of UA-553, based upon the flightpath derived from ARTS-III data and the engine sound spectrogram study, was compared with the theoretical performance characteristics of the B-737. First, the aircraft's drag as a function of airspeed was computed for the different approach configurations (combinations of flap, landing gear, and spoiler positions) that could have been used. Next, the various drag values and the thrust values derived from the General Electric study were used to determine the resultant forces acting on the aircraft. These forces, in turn, were compared with the vertical velocity and longitudinal acceleration values shown in the approach profile, starting with the descent from 4,000 feet, and ending with the activation of the stickshaker.

For purposes of this examination, it was assumed that the ARTS-III altitude data offered a more accurate parameter than the calculated airspeed trace, which included the tolerance of ARTS-III positional measurements, as well as errors introduced by inclusion of estimated wind data. For this reason, the calculated rate of descent was examined with the longitudinal acceleration and airspeed treated as variables. To provide a plausible set of initial conditions, it was further assumed that the 15° flap extension at 1423:20, inferred from CVR sounds, was made at the placard airspeed of 195 knots indicated airspeed (KIAS), approximately 10 knots below the airspeed derived from the ARTS-III data. Subsequent changes in configuration were keyed to intracockpit conversation and other sounds similar to lever movements recorded on the CVR.

It was determined from this study that the profile of the accident aircraft could be matched closely with the theoretical performance capability of the B-737 for that part of the approach preceding passage of the Kedzie OM. The correlation was achieved with the flaps extended 15°, landing gear up, and partial flight spoiler extension coincident with the initiation of the descent from 4,000 feet at 1424:10 approximately. The theoretical deceleration to this point would have produced an airspeed of 157 KIAS. At a 750 ft/min rate of descent, the aircraft would have continued to decelerate and would have reached an airspeed of 140 KIAS at 1425:32; at that time an increased rate of descent to approximately 1,250 ft/min would have produced a positive acceleration. Recorded cockpit sounds indicate that the landing gear was extended at 1425:50, and that the flaps were repositioned at 1426:00, although the position to which the flaps were extended was not apparent. The theoretical airspeed at this time would have been 152 KIAS.

The ARTS-III altitude trace shows that the aircraft momentarily levelled off at 2,200 feet m.s.l., for approximately 12 seconds, which would have resulted in a decay of airspeed to 126 KIAS. A rate of descent of approximately 1,550 ft/min was established as the aircraft passed the outer marker. This descent rate was maintained until the aircraft levelled off about 1,000 feet m.s.l. The correlation of the CVR with the ARTS-III data indicates that the stall warning stickshaker commenced 6 to 7 seconds after the aircraft levelled off. In order theoretically to produce such a condition, it is necessary to assume that the aircraft was in a configuration which resulted in sufficient drag to prevent a high positive acceleration during this final descent. It was shown in this study that had 30° flaps been selected at 1426:00, and had the spoilers been extended to the flight detent position upon establishing the 1,550 ft/min descent, the aircraft would have started to level off at MDA approximately at 133 KIAS. Any configuration producing less drag would have resulted in the aircraft levelling off at a higher airspeed.

In the 30° flap, gear down, flight detent spoiler configuration with a combined engine thrust of 5,900 pounds, as indicated by the engine sound spectrogram, the aircraft would have decelerated approximately at 2 knots per second after levelling off. The theoretical speed for stickshaker activation in this configuration is 116 KIAS. Without making allowances for levelling-off technique or increase in thrust, it would have taken approximately 8½ seconds under these conditions to decelerate from 133 to 116 KIAS.

Under similar conditions, but with the flight spoilers retracted, the deceleration rate was computed to be 1.1 knots per second. Based on the stickshaker activation speed of 105 KIAS, about 25 seconds would have elapsed between the aircraft level-off and activation of the stickshaker.

1.15.4 Simulator Tests

Two series of flight simulator tests were conducted to compare the performance of the B-737 in various approach configurations with the flight profiles developed from the ARTS-III data and to explore the effects of different techniques in recovering from the approach-to-stall flight regime.

The first test series was conducted prior to the receipt of the engine sound spectrogram findings; consequently, a flight idle engine thrust level during the latter portion of the descent profile was chosen for investigative purposes. Engine thrust levels ranging from takeoff thrust to as low as 1.50 EPR were investigated during the recovery phase of the profile.

The engine sound spectrogram study demonstrated that thrust levels in excess of flight idle were used throughout the final moments of the flight. Therefore, a second performance profile, incorporating the thrust levels derived from the General Electric data, was developed and investigated in a second series of simulator tests. The results of these tests validated the new performance study. To attain a 1,500 ft/min descent without allowing a significant speed buildup at a thrust level corresponding to 59 percent N_1, it was necessary to use the following drag configuration: 30° flaps, landing gear down, and full flight spoiler extension.

The effect of flight spoiler positioning and thrust application upon the time interval between the level-off and the activation of the stickshaker was investigated. The entry configuration was established as 30° flaps, landing gear down, flight spoilers in detent, and the engine thrust level at 59 percent N_1. With the thrust maintained at 59 percent N_1, the time interval from level-off to stickshaker speed ranged from 4 to 9 seconds, and the stickshaker speed varied from 120 to 124 KIAS. When the thrust was advanced to 76 percent N_1 at level-off, or when the thrust was maintained at 59 percent N_1 with the spoilers stowed prior to level-off, the time interval from level-off to stickshaker activation ranged from 20 seconds to 25 seconds.

The flap setting, spoiler position, and engine acceleration were varied during the final phases of several of the tests. The highest thrust applied was 76 percent N_1; this was insufficient either to accelerate the aircraft, or to maintain level flight, under any combination of flaps in excess of 15° and spoilers more than halfway extended. On three runs the flaps were retracted to 15° at stickshaker speed; this resulted in the immediate onset of buffeting. Extending the flaps to 40° stopped the buffeting but not the stickshaker. The retraction of the spoilers at the latter flap setting stopped the stickshaker, even when the retraction was delayed until 110 KIAS.

1.15.5 B-737 Flight Tests

Flight tests were conducted to correlate the airspeed, configuration, and thrust requirements during the descent from 4,000 feet, previously determined from performance and simulator studies, and to investigate, in more detail, the flight performance characteristics of the B-737 in the approach-to-stall regime. The results of these tests were affected to a limited extent by thermal activity and wind shear in the test area.

For safety considerations the flight tests were conducted at pressure altitudes between 6,000 feet and 8,000 feet. Therefore, it was necessary to apply theoretical corrections to the test conditions to make them comparable to the accident conditions. As with the initial simulator study, the flight tests were also conducted before the results of General Electric's engine speed study were available.

The flight test findings provided sufficient data to substantiate the validity of the theoretical analyses described in 1.15.3. To examine the apparent flight profile from outer marker passage until level-off at the MDA, a 1,500 ft/min descent was established in the 30° flap, gear down configuration with spoilers extended to the flight detent position (maximum in-flight extension), and thrust equivalent to 55 percent N_1. At the existing temperature and altitude conditions, this power setting would theoretically produce a combined engine thrust of approximately 3,760 pounds. At an indicated airspeed of 135 knots (147 KTAS), a deceleration of 0.57 knot per second was evident. Using the B-737 certification drag data, a theoretical value of 0.66 knot per second was calculated for these conditions.

Tests relating to stickshaker and stall entry speeds were conducted from a level, flight idle thrust condition with 30° flaps and landing gear down; the flight spoiler position was varied. With the flight spoilers stowed, the stickshaker activated at 108 knots and stall buffeting occurred at 104 knots. With flight spoilers halfway extended, stickshaker activation occurred at 113 knots and stall buffeting at 108 knots. In both configurations, stall buffeting was experienced within 4 seconds of stickshaker activation.

Maintenance of level flight at an altitude of 8,000 feet and an airspeed less than the stickshaker activation speed, with 30° flaps, landing gear down, and flight spoilers stowed, required an engine power setting of 1.62 EPR. The combined thrust produced at this power setting would, theoretically, be approximately 12,980 pounds. This value was similar to the value extrapolated from certification test data which indicate a required thrust of 12,500 pounds for these same conditions.

Another series of tests was designed to examine the effect of configuration changes and thrust application on recovery from the stall regime. Deceleration to stickshaker speed was accomplished from both level and descending flight with the engines at idle thrust. The entry configurations were established as: 30° flaps, landing gear down, and with the flight spoilers in the stowed, halfway extended, and flight detent positions.

Recovery techniques consisted of power application to between 1.7 and 1.8 EPR (approximately 8,500 pounds of thrust per engine), reduction of the pitch attitude to an approximately level attitude, and repositioning of the wing flaps as a test variable, i.e., either retracted to 15° or extended to 40° at the initiation of the recovery. Spoilers were left in their originally selected position. In all cases, recovery was effected with power application and a simultaneous decrease in pitch attitude. The pitch attitude at the onset of stickshaker activation was consistently near 12°, as shown on the captain's attitude indicator. The stabilizer trim corresponding to this position was seven units noseup. Trim was not changed during the recovery sequence. A loss of altitude of 150 to 500 feet occurred during all recoveries. The loss of altitude when the flaps were retracted to 15° was greater than that experienced when the flaps were left at 30° or extended to 40°. Notwithstanding the differences in stickshaker activation speed, the differences in flight spoiler positions upon entry into stall buffeting appeared to have little effect on the loss of altitude consistent with the recovery technique.

1.15.6 Central Air Data Computer (CADC) Examination

Electronic measurement of the fine altitude synchro in the altitude module of the captain's CADC showed a phase angle of 46.95° which corresponded to a pressure altitude of 652 feet. This altitude, corrected to the local barometric pressure (30.05 inches) at the time of the accident, was equivalent to an altimeter reading of 772 feet m.s.l. A similar measurement of the first officer's CADC fine altitude synchro showed a phase of 43.08° which corresponded to a pressure altitude of 598 feet and to a corrected altimeter reading of 718 feet m.s.l.

A functional test of the captain's CADC showed normal operation throughout its operating range; no out-of-tolerance condition was observed. A test of the first officer's CADC also showed satisfactory operation; however, the altitude readings were consistently 40 feet low throughout its operating range. A test was conducted in which an undamaged CADC unit was exposed to heat; a heat-induced altitude error was noted similar to that found in the first officer's CADC.

1.15.7 Description of B-737 Ice Protection Systems and Certification

Ice protection systems in the B-737 include wing anti-icing, engine inlet anti-icing, Pitot static heat, and windshield heat. The wing anti-icing and the engine anti-icing systems both consist of ducted bleed-air providing protection to the leading edge slats, the cowl leading edge, the inlet guide vanes, nose dome, and engine inlet pressure sensing (PT_2) probe. The Pitot static tube, stall warning sensor, total temperature probe, and windshields are electrically heated. Like the B-707 and B-727, the B-737 has no provision for inboard wing leading edge or empennage anti-icing.

During certification of the B-737, it was shown that the aircraft's ice protection systems were capable of preventing ice formation on the heated surfaces under conditions of maximum continuous and intermittent icing specified in Part 25 of the Federal Aviation Regulations (FAR) when engine speed is maintained above 55 percent N_1.

The JT8D engine was certificated in accordance with Part 33 of the FAR. It was demonstrated during the certification program that the engine would perform in the icing environment as required by the regulations.

The Boeing Company performed an analysis to determine the engine power required to provide sufficient heat to the engine cowl and nose dome to prevent ice accumulation under the meteorological conditions existing at the time of the accident. The analysis indicated that the heat provided to the engine anti-ice system at idle power would have been sufficient to maintain the cowl leading edge surfaces and nose dome free of ice. Although a small amount of runback ice could have formed aft of the heated leading edge surfaces of the cowl, the maximum accumulation during the approach period would have produced negligible effects on engine operation.

1.16 <u>United Air Lines Flight Crew Procedures</u>

Certain procedures listed in the company's Flight Operations Manual and Flight Handbook were pertinent to the final portion of the flight.

The Nonprecision Approach and Missed Approach Procedure (MAP) profile in the Flight Proficiency section of the Flight Manual (see Appendix H) showed that the final descent check was to be accomplished before the final approach fix (FAF) was reached. The profile also indicated that the recommended descent rate from the FAF was approximately 1,000 ft/min, and that the aircraft was to be placed in the approach configuration before reaching the FAF.

Pertinent extracts from the flight manual are quoted, in part, as follows:

"<u>Missed Approaches</u>

As the missed approach is initiated, the pilot should advance the throttles and rotate to the go-around attitude (approximately 15°), simultaneously calling for takeoff thrust and flaps to the missed approach setting.

"<u>Approaches to Stalls</u>

At first warning of impending stall advance the throttles and lower the nose, simultaneously calling for takeoff thrust and flaps to the recovery setting; gear up at first indication of positive rate of climb.

"<u>Approach Descent</u>

After completion of the Final Descent Check List, the Captain will announce the target approach speed. When the airplane is 1,000 feet above field elevation, the F/O will crosscheck the flight instruments and announce: 1,000 feet above field elevation, flight instruments check.

"At 500 feet above field elevation as determined by barometric altimeter, the F/O will announce: 500 feet above field elevation. Starting at 500 feet above field elevation and at approximately each 100 feet increment, he will call out only displacement or deviation errors as pertinent. ... At approximately 100 feet above minimum altitude by use of the barometric altimeter, he will announce: approaching Minimums. At minimum altitude by use of the barometric altimeter (Radio Altimeter for CAT-II approach), he will announce: Minimums ... If the Captain executes a missed approach, he will announce: Going Around.

"Use of Anti-ice Equipment

It is difficult to specifically define when to use (or not use) anti-icing and to establish any appropriate set technique. The following represent general guides on operation: (When in doubt, use it).

"In icing conditions, maintain engine RPM above approximately 55 percent N_1 for satisfactory anti-icing.

"If ice does form on the engine inlet, disturbance of the airflow can produce engine surging, high EGT's, flameout, etc. With even a small amount of ice present, turning on Engine Anti-Ice will cause the melting ice to go through the engine and may cause violent engine surging at intervals of one to two minutes. Throttle adjustments should be slow and deliberate to avoid exposure to engine flame-out."

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

The crewmembers were properly certificated and qualified for the flight. There was no evidence of any medical condition that would have incapacitated the crew, or of any interference with the crew in the performance of their duties; nor did the Safety Board's investigation reveal any evidence of sabotage or foul play in connection with this accident. The nature and severity of the injuries sustained by the nonsurviving occupants was consistent with the nature of the impact and the combined destruction of the aircraft and the houses. The finding of elevated levels of carbon monoxide and cyanide in some of the victims was consistent with death due to smoke inhalation in the conditions existing during the postcrash fire.

The aircraft was certificated, maintained, and equipped in accordance with FAA regulations. The aircraft weight and c.g. were both within limits specified for the intended landing at Midway. There was no evidence of any failure or malfunction of the aircraft structure, powerplants, or control system before impact.

Both CADC units were capable of normal operation, but their altitude synchros, as recovered, showed an altitude higher than that of the crash-site. The altitude differences, which could have been transmitted from the CADC units to the captain's and first officer's servo altimeters, were 157 feet and 103 feet, respectively.

The two CADC units are connected to static sources located on independent Pitot/static probes which have no common connections. The same probes contain independent static sources for the airspeed indicators. A static source error equivalent to an altitude error of 100 feet could produce a 10-knot airspeed indicator error in the same direction, i.e., if the aircraft is higher than the altimeter indicates, the airspeed indicator will show a speed that is higher than the aircraft's actual airspeed.

Several sources for common errors in the two independent systems were considered. One was ice, which could have accumulated on the Pitot/static probes. However, since both probe heat switches were found in the "ON" position, and since examination of the filaments of the probe head indicating lights showed that probe heat was energized at the time of impact, it is unlikely that probe icing was the source of error in this case. Another source of error could have been the effect of the aircraft's extreme nose-high attitude during the final moments of flight. According to The Boeing Company's flight test data, pitch angles within the stall buffeting region can produce static system errors that result in altimeter readings 60 feet higher than the actual altitude. Also, if electrical power to the CADC was interrupted while the aircraft was in a nose-high attitude at impact, the Pitot/static sensing ports could have been 20 feet or more above the elevation of the crash site. Additional errors inherent in the reported barometric pressure correction at the time of impact could account for still another 15 to 20 feet. Since it is possible, as shown above, to account for a significant portion of the difference between impact elevation and the CADC altitude computations at the time of power interruption, the Safety Board concludes that the static system errors reflected in the CADC readings at impact do not have a bearing on the events that occurred at MDA.

The flight's progress was routine until arrival in the Chicago area and the start of the approach descent. Although an approach clearance was not issued to UA-553 in accordance with the applicable ATC procedures, the radio and cockpit conversations, and the subsequent events leave no doubt that the controller and the crew understood that the flight was cleared for the approach.

The approach controller requested a speed reduction to 180 knots when the aircraft was approximately 15 nmi from Midway Airport, in level flight, at 4,000 feet, and at an airspeed of approximately 230 knots. Eighty seconds later the controller requested a further reduction in airspeed to 160 knots. Immediately thereafter, the CVR indicates a sound believed to have been made as the flap lever was moved to the 15° position. Although the ARTS-III data showed an airspeed in excess of 200 knots at that time, it is more likely that 15° flaps were selected at or below the flap limit speed of 195 knots, as the aircraft was decelerating. The engine power setting remained at approximately 63 percent N_1 during that time period. When the controller advised the flight to slow to approach speed, 106 seconds after he issued his first speed advisory, the aircraft's speed was still in excess of 180 knots. The deceleration rate for that entire period was less than the aircraft's deceleration capability, provided the thrust had been reduced and the flight spoilers extended.

The approach controller tried to maintain adequate separation between UA-553 and the preceding Aero Commander by requesting the airspeed adjustments. These speed advisories were within the scope of proper air traffic procedures, since the function of ATC is to effect adequate separation as well as expeditious flow of traffic. The flightcrew acknowledged the advisories but did not comment on them in cockpit conversation. If a pilot has any problems in complying with ATC advisories, he can use his prerogative to abandon the approach at any point, or to ask for an alternative course of action.

When the tower controller could not make Runway 31L available to the flight by diverting the Aero Commander to land on Runway 31R, he issued a missed approach clearance to UA-553. The fact that the onset of the stickshaker activation coincided with the first word of the missed approach clearance indicates that this clearance had no bearing on the events at MDA.

In view of the above circumstances, the Board concludes that ATC was not a factor in this accident.

At 1423:20, the controller cleared UA-553 to descend to 2,000 feet. Although the first officer acknowledged leaving 4,000 feet immediately after receipt of the descent clearance, the evidence shows that the aircraft continued to decelerate in level flight, and that the N_1 speed was not reduced until about 35 seconds later. The performance studies and simulator tests show that the flight spoilers were probably partially extended at this time. The aircraft departed 4,000 feet about 1424:15 when a rate of descent of approximately 750 ft/min was established. The performance study indicates that the descent was initiated at an airspeed of approximately 155 knots.

The reason for the crew's relatively slow response to ATC advisories appears to be their unawareness of the exact distance to the Kedzie OM. There was no DME associated with this approach; and the crew did not request, or receive, distance advisories from the approach controller. Another method for the crew to determine their position on the localizer with regard to the OM was the use of the Calumet intersection, as depicted on the pertinent approach chart. The distance from Calumet to the Kedzie OM is 6.9 nmi. However, there is no direct or indirect reference to the use of the Calumet intersection recorded on the CVR. The conversation from the time of level-off at 4,000 feet until the aircraft passed the Calumet intersection deals mainly with the inoperative status of the FDR and means to troubleshoot it.

That the crew was unaware of Kedzie's proximity is also evident in the unhurried manner in which the descent to Kedzie was executed. CVR and performance data indicate that the descent from 4,000 feet was started with the landing flaps extended to 15° and with thrust equivalent to 59.1 percent N_1 engine speed. The 750 ft/min rate of descent was increased to between 1,050 and 1,250 ft/min about 1½ minutes later when the flight reported "We're out of three for two." When the controller responded that the flight was number two on the approach, the captain called for the landing gear to be lowered. Shortly thereafter, the flap lever was manipulated; performance and simulator studies indicate that the flaps were probably extended to 30° at that time. The increased lift, as the flaps extended, caused a momentary level-off at 2,200 feet, which should have resulted in an airspeed decay from approximately 150 to 130 knots. The throttle position remained constant with engine power at 58 to 59 percent N_1.

The cumulative effect of the crew's apparent failure to ascertain their position on the localizer course was that the flight crossed the Kedzie OM at about 2,200 feet m.s.l., 700 feet above the published minimum crossing altitude. The Kedzie beacon signal may have been the crew's first positive indication of their inbound position. At that time, the aircraft's distance from Runway 31L was 3.3 nmi which was equivalent to 1 minute 39 seconds flying time at an average ground speed of 120 knots. When he recognized the situation that was developing, the captain increased the rate of descent to approximately 1,550 ft/min and immediately called for the final descent check. The company's nonprecision approach profile indicated that this checklist was to be completed before crossing the OM. Testimony by company flight management personnel at the public hearing indicated that this procedure was not mandatory in a nonprecision approach and that it depended primarily on the distance between the final approach fix (OM) and the runway. Considering the short distance between Kedzie and Runway 31L, the captain's delay in calling for the final descent check does not appear to be a preplanned course of action on his part. The resulting increase in the cockpit workload and disruption of crew coordination during the most critical phase of the approach turned out to be key elements in the development of the accident sequence.

The absence of FDR information, the imprecision of the ARTS-III data, and the high ambient noise level of the CVR recording preclude a precise determination of the nature and tempo of events during the 61 seconds from the call for the final descent check until impact. However, certain events and flightpath parameters can be identified. The ARTS-III data indicate that the approximately 1,550 ft/min descent was maintained until the aircraft reached an altitude between 1,000 and 1,100 feet m.s.l. The data further indicate that there was no gradual reduction in descent rate since the transponder returns received by the ARTS-III system on successive antenna sweeps prior to the level-off were 1,300, 1,100, and 1,000 feet. Considering the system resolution of ± 50 feet, the significance of the 200-foot increment is that a minimum of 100 feet of altitude change was recorded during the nominal 4 seconds between antenna returns. This implies that the aircraft still had a descent rate of at least 1,500 ft/min within

4 seconds of reaching level-off altitude. The 1,500 ft/min descent from the outer marker to the MDA was in excess of that recommended in the company's operations manual.

The indicated airspeeds derived from the ARTS-III data showed a gradual deceleration during this descent, with level-off being initiated approximately at 120 knots. The theoretical performance of the B-737 conflicts somewhat with this evidence. The CVR sound spectrogram study showed that the power remained at 58 percent to 59 percent N_1 throughout the descent. With the thrust produced under the existing conditions, a 1,550 ft/min descent can be achieved in a high-drag configuration, but the stabilized airspeed will be in excess of 130 knots. The performance study indicated that had 30° flaps been selected at 1426:00 and had the spoilers been extended to the flight detent position upon establishing the 1,550 ft/min descent, level-off would have been initiated approximately at 133 knots. Any configuration producing less drag would have resulted in a higher level-off airspeed, which would have been less compatible with the subsequent events. The aircraft's performance corresponding to this thrust and drag configuration was validated by the B-737 simulator tests. Therefore, the Safety Board concludes that level-off airspeed was closer to the theoretical value and that the final descent was accomplished in a 30° flap, landing-gear-down configuration with the spoilers extended to the flight detent position.

The first and second officers did not complete the checklist until the captain had leveled off approximately at 1,000 feet. As a result, the first officer did not make any of the required altitude callouts, nor does it appear that he was monitoring airspeed and rate of descent. In regard to his checklist response that the spoilers were "armed," it is noted that the green "armed" light is illuminated whenever the spoiler lever is moved out of its forward "stowed" position and placed in the "armed" detent (spoilers retracted and the system ready for automatic deployment upon landing) or in any position aft of that, including the "flight" detent (maximum in-flight deployment). Since the flight spoilers affected the aircraft's performance and were needed to expedite the descent, the first officer probably would not have retracted them on his own initiative. Therefore, to account for this checklist item in the limited time available, he may have based his response on the illumination of the light, rather than on the position of the speed brake lever.

The sound of the click recorded in conjunction with this checklist item could not be definitely identified. Although the CVR transcript interprets this sound as "similar to sound made by moving speed brake lever to armed position," it was later determined that such a click could also have been produced by the tapping of the springloaded spoiler lever or by moving the lever into the flight detent.

ARTS-III and CVR data show that the level-off coincides with the final checklist response. The first officer's 1,000-foot call, about 1 second after his final checklist response, seems more of an afterthought than the required callout of MDA. The rather abrupt level-off reflected in the ARTS-III data suggests that, because the captain's attention was occupied by other instruments and checklist activities, the realization that he was rapidly approaching MDA may have come suddenly, and late. Considering the pilot reports of a 500-foot ceiling between the OM and the airport, it is also possible that visual ground contact, coupled with a high descent rate, prompted the immediate level-off.

The rush of cockpit activities at this point, the first officer's routine callout that the spoilers were "armed," and the fact that the spoilers are seldom used during the final segment of an instrument approach, may well have caused the captain to overlook the position of the spoilers at level-off. This probability is supported by the events that followed.

ARTS-III, CVR, and engine sound correlation shows that the engine thrust was not increased in anticipation of the level-off. The throttles were repositioned to produce 72 percent N_1 on one engine and 79.2 percent N_1 on the other within 6 to 7 seconds after initiation of the level-off maneuver. Although the addition of power may have been intentionally delayed because of the captain's observation of an airspeed higher than $V_{reference}$, the asymmetrical development of thrust was probably associated with the abrupt nature of the maneuver. Probably more significant in this context is the fact that the captain moved the throttles to a position that corresponded closely with the thrust required to maintain his reference speed in the normal landing configuration with the spoilers stowed.

The stickshaker started to sound as the power was increased, and the sound continued for the 20 seconds remaining until impact. The ARTS-III data indicate that the aircraft continued to maintain level flight for 8 to 10 seconds of this time period.

The activation of the stickshaker indicates that the angle of attack had reached a point corresponding to a speed of approximately 9 percent above the stall value. With a 30° flap configuration, the stickshaker would activate at a body angle of attack of approximately 13°; with the flight spoilers stowed, this would correspond to an airspeed of 105 knots. If the flight spoilers were deployed to the flight detent position, the airspeed corresponding to stickshaker speed would have been about 116 knots at the same angle of attack; in either case, both of these speeds are significantly below the reference speed of 125 knots.

The main consideration in the deceleration of the aircraft from reference speed to stickshaker speed is that the thrust to counter the total drag of the aircraft in level flight was insufficient. In the 30° flap, gear down, flight detent spoiler configuration, with a thrust setting corresponding to that used during the final descent (58 to 59 percent N_1; 5,900 pounds thrust), the aircraft would have decelerated approximately at 2.0 knots per second in level flight. The transient condition produced by an increased load factor during the level-off would produce an even higher deceleration. In conjunction with the probable airspeed at level-off and the stickshaker activation speed with the spoilers deployed, this deceleration rate correlates closely with the indicated time sequence of events.

With the flight spoilers retracted, the aircraft deceleration would have been reduced to 1.1 knots per second. In conjunction with the lower stickshaker activation speed (105 knots) approximately 25 seconds would have elapsed between level-off and stickshaker activation. Such a time lapse was not supported by the evidence. Therefore, the Safety Board concludes that the flight spoilers remained in the flight detent position during and subsequent to level-off. The Board further believes that the captain, caught in a rapid tempo of unusual events, was unable to analyze the situation in time to apply effective corrective action.

The engine acceleration after level-off produced an asymmetrical thrust of 8,000 pounds on one engine and 5,900 pounds on the other, a total of 13,900 pounds. A thrust in excess of 12,500 pounds should have been sufficient to accelerate the aircraft out of the stickshaker regime if the flight spoilers had been stowed. With the spoilers in the flight detent position, however, a total thrust of 14,500 pounds would have been required merely to maintain unaccelerated level flight within the stickshaker regime. With less thrust, any attempt to maintain level flight would require an increase in pitch attitude resulting in a continuing deceleration and the eventual reaching of the stall angle of attack.

The specified recovery procedure for an approach to a stall is to lower the nose, apply takeoff thrust, retract the flaps to 15°, and retract the gear when a positive rate of climb is achieved. The performance and simulator studies indicate that the B-737 has sufficient thrust capability to accelerate out of the approach-to-stall regime, even with the spoilers extended. If takeoff thrust is produced within 2 or 3 seconds of stickshaker activation, little or no altitude has to be sacrificed.

The stickshaker sound started while the engines were still accelerating in response to the captain's application of level-off power. CVR evidence suggests that instead of applying more power, the captain's immediate reaction was to reconfigure the aircraft; within 2 seconds of stickshaker onset, there was a sound indicative of flap lever movement. If the flaps were retracted to 15° at this time, the associated loss of lift would cause the aircraft to settle. It is quite likely that the captain would counter this situation by increasing the nose attitude even further. Eyewitnesses and surviving passengers both attested to such an increase in pitch attitude.

The subsequent CVR comments, "want more flaps," "flaps fifteen," "I'm sorry," and the sound of another click similar to flap lever movement can be interpreted as the crew's realization of the adverse effect of flap retraction and their corrective action by selecting 40° flaps. Such a final selection was verified by wreckage examination. Although the CVR sound spectrogram does not conclusively show a subsequent power increase, it seems probable, based upon witness observations and engine examination, that takeoff thrust was eventually applied. At this point, however, the angle of attack may have been so high as to make recovery impossible even with full thrust developing.

That the crew realized the position of the flight spoilers during this 20-second sequence of events is not evident. After the accident, the spoiler lever was found in the forward or stowed position, and the spoilers in the retracted position. However, the postimpact condition of the center control pedestal and the possibility of spoiler retraction when hydraulic pressure was lost during the impact make this evidence inconclusive.

The postimpact position of the horizontal stabilizer trim was determined to have been 9½ units noseup, which would correlate more closely with a spoiler-stowed configuration at speeds within the stickshaker regime. Boeing data indicate that a trim setting of 6½ units would more nearly correspond with a 30° flaps, gear down, spoiler extended configuration, at an airspeed of 130 knots and a power setting of 55 percent N_1. Sounds recorded on the CVR indicate that the pitch trim was changed coincident with level-off. Whether the trim was subsequently changed to compensate for spoiler retraction, or for changes in flap setting, or as an instinctive action just before impact, could not be determined. The sounds generally associated with trim activation might have been masked by the stickshaker sounds during the final 20 seconds of flight. Although the position of the stabilizer trim as found cannot be reconciled with that which would be expected for the existing conditions, the Board believes that the significance of this condition is outweighed by the evidence regarding the deployment of spoilers during the final descent and level-off.

Since the flight was operating in icing conditions described as light to moderate by pilots flying in the same area at the time of the accident, the Board considered the possible influence of icing in producing a thrust/drag relationship which might have caused the aircraft to decelerate into a stall condition. UA procedures specify that engine anti-icing be turned on when an aircraft is flying in clouds below 20,000 feet with temperatures at or below freezing. The engine anti-icing valves and switches were found in the open and on positions, respectively, upon examination. Although there was no cockpit conversation relative to icing conditions or anti-icing activation, it seems reasonable to assume that engine anti-icing was activated in accordance with UA procedures. In addition, during the descent engine N_1 rpm was maintained at or near the minimum N_1 speed of 55 percent recommended for satisfactory anti-icing in icing conditions. Observations of survivors and ground witnesses do not indicate a problem with the engines that would normally be associated with the accumulation of engine ice, i.e., sounds of compressor stall or rapid surging due to ice ingestion when the engines responded to thrust application. For these reasons, the Safety Board concludes that engine icing was not a causal factor in this accident.

The weather conditions during the approach of UA-553 were also conducive to airframe icing. The aircraft would have been subject to these conditions for approximately 6 minutes. Pilots conducting approaches to Midway during the time period involved reported that the ice accumulation on their aircraft was not significant. The pilot of a DC-9 which operated in these conditions for about 7 minutes reported less than 1/4-inch ice accumulation.

From the examination of the wing anti-ice valves it was determined that the wing anti-ice system was off at impact. This position would be compatible with company practices which recommend turning off the wing heat before the final approach to avoid a thrust penalty in case of a missed approach, and to prevent landing with a hot wing. There were no remarks on the CVR that indicated crew activity in regard to wing anti-ice. The pressing cockpit activities during the final part of the approach make it unlikely that the wing anti-icing system was deactivated at this time. This would imply that the crew considered the existing icing conditions not severe enough to apply wing anti-icing. Finally, it was demonstrated during the B-737 aircraft certification tests, and confirmed through analytical evaluation during this investigation, that ice accumulations on the airframe surfaces consistent with the certification requirements would not significantly affect the controllability of the aircraft. Moreover, the drag increment produced by an ice accumulation 3 inches thick on the leading edge of the empennage surfaces is less than 1,000 pounds at 120 knots. Comparably, a drag increment of approximately 3,500 pounds is produced by flight detent spoiler extension. In view of the above, it is concluded that airframe icing was not a causal factor in this accident.

In summary, the preponderance of evidence indicates that the rush of cockpit activities during the final descent caused a breakdown of the safeguards inherent in the tasksharing of a crew. The error-provoking environment set the stage for the crew's failure to notice that the spoilers were still extended at level-off and to arrest the rapid deterioration of airspeed that followed.

Although the greater portion of this analysis deals with the events surrounding the level-off, the Board wishes to emphasize that the accident sequence was triggered by the captain's failure to exercise positive flight management earlier during the approach.

2.2 Conclusions

a. Findings

1. The flightcrew was certificated and qualified to conduct this flight.

2. The aircraft was certificated, equipped, and maintained in accordance with existing FAA rules and company procedures. Aircraft weight and center of gravity were within limits for the intended landing at Midway.

3. The aircraft and its associated systems, flight controls, and powerplants, with the exception of the flight data recorder, were airworthy.

4. No evidence was found of sabotage or foul play in connection with this accident.

5. The engine anti-icing system was on during the final approach, and the engines were operated above the minimum thrust settings recommended for satisfactory operation of the anti-icing system.

6. The light to moderate icing conditions to which the aircraft was exposed would not have compromised the capability of the aircraft to level off and execute a successful missed approach.

7. The ATC handling of the flight, including the timing of the issuance of the missed approach clearance, did not compromise the safety of the flight.

8. The flight was slow in responding to ATC requests for speed reductions and to the descent clearance.

9. The crew did not use one of the available means to determine their distance to the outer marker.

10. The aircraft crossed the outer marker about 700 feet above the published minimum crossing altitude.

11. The captain did not call for the final descent check until the aircraft had passed the outer marker; the distance from the outer marker to the runway was 3.3 nmi.

12. There was a breakdown in crew coordination during the most critical phase of the approach.

13. The first officer did not make the prescribed altitude call-outs during the approach.

14. The flight spoilers were deployed to the flight detent position for the final descent from the Kedzie OM and remained in this position during the level-off at MDA.

b. <u>Probable Cause</u>

The National Transportation Safety Board determines that the probable cause of this accident was the captain's failure to exercise positive flight management during the execution of a nonprecision approach, which culminated in a critical deterioration of airspeed into the stall regime where level flight could no longer be maintained.

3. RECOMMENDATIONS

Recommendations concerning the crash survival aspects of this accident were combined with those of two other recent accidents and submitted to the FAA in a letter dated June 25, 1973. (See Appendix I.)

In view of the fact that adherence to established operational procedures and practices would probably have prevented this accident, the Board reiterates its often-expressed concern about the apparent lack of crew coordination and cockpit discipline during nonprecision approaches.

Two of the accident reports released by the Board in 1972 (NTSB-AAR-72-11 and NTSB-AAR-72-31) contained specific recommendations in this regard. In the first report, the Board included the complete FAA's Air Carrier Operations Bulletin No. 71-9 in the recommendations section. The subject of the bulletin is: Training Emphasis on Nonprecision Approach Procedures and Interpretation of Low Visibility Weather Reports. This bulletin, in essence, summarizes the common faults noted in nonprecision approaches and makes several pertinent recommendations. The following quotation from this bulletin illustrates its main theme:

> "Perhaps we should stop using the philosophy of nonprecision and face up to the need for standards that all phases of flight should be based upon precision and professionalism. Still another area in the conduct of nonprecision approach has to do with the attitude, cockpit discipline and crew coordination of the flight crew. Recent events strongly indicate a widespread lack of appreciation for the importance of these factors. Substandard attitude, discipline and coordination are apparent to the degree that many approaches are being flown in a hit-or-miss fashion rather than in a disciplined by-the-book procedure."

In the second report, the Board recommended that the FAA:

1. Reemphasize to all flightcrew members the necessity for total crew coordination and adherence to approved procedures.

2. Insure that all flightcrew members are currently apprised of the contents of Air Carrier Operations Bulletin 71-9, emphasizing that a "nonprecision" approach requires as much, if not more, crew coordination than a "precision" approach because of the lack of precise guidance from electronic navigational aids outside the aircraft.

As an additional step in drawing attention to this bulletin, the Board will forward copies to the organizations listed below with the recommendation that its contents be used, together with this accident report to stress the unique demands for crew coordination and vigilance during nonprecision approaches:

Allied Pilots Association
Air Line Pilots Association
Aircraft Owners and Pilots Association
Flight Safety Foundation, Inc.
National Business Aircraft Association, Inc.
National Pilots Association
National Air Transportation Conferences, Inc.
Air Transport Association of America
National Air Carrier Association, Inc.
Association of Local Transport Airlines

In view of the role of the flight spoilers in this accident and the indication that the crew was not aware of the reason for the higher-than-normal stall warning activation speed, the Safety Board concludes that certain crew training deficiencies exist and recommends that the Federal Aviation Administration:

1. Reassess and improve the methods used, both in flight manuals and in simulator or flight training, to familiarize flightcrews with the effects of spoilers on aircraft characteristics and stall warning devices. (Recommendation A-73-73.)

2. Issue an advisory bulletin to alert pilots and operators to the hazards of the improper use of spoilers. (Recommendation A-73-74.)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

John H. Reed, Chairman, was not present and did not participate in the adoption of this report.

August 29, 1973

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Board received notification of the accident at 1440 c.s.t., on December 8, 1972, from the Federal Aviation Administration. An investigation team was immediately dispatched to the scene of the accident. Working groups were established for Operations, Air Traffic Control, Witnesses, Weather, Human Factors, Structures, Powerplants, Systems, Maintenance Records, and Flight Recorders. An additional group was formed later for Aircraft Performance. Parties to the Investigation included: United Air Lines, Inc., the Federal Aviation Administration, The Boeing Company, Pratt and Whitney Aircraft Division of the United Aircraft Corporation, Air Line Pilots Association, Professional Air Traffic Controllers Organization, and the International Association of Machinists and Aerospace Workers.

2. Hearing

A public hearing was convened by the Safety Board at Rosemont, Illinois, on February 27, 1973. Parties to the hearing were: United Air Lines, Inc., the Federal Aviation Administration, The Boeing Company, Pratt and Whitney Aircraft Division of United Aircraft Corporation, Air Line Pilots Association, and the Professional Air Traffic Controllers Organization. A deposition was taken at Chicago, Illinois, on June 13 and 14, 1973.

3. Reports

A preliminary report on this accident was issued by the Safety Board on January 19, 1973.

APPENDIX B

CREW INFORMATION

Captain Wendell Lewis Whitehouse, aged 44, was employed by United Air Lines on January 30, 1956. He held Airline Transport Pilot Certificate No. 1159888, issued on October 3, 1968, with type ratings in the Douglas DC-6/7 and the Boeing 737 aircraft. He also held Flight Engineer Certificate No. 1386803. He was upgraded to captain in the Boeing 737 on October 29, 1968.

Captain Whitehouse flew an unsatisfactory Boeing 737 proficiency check on April 29, 1970; a recheck was completed satisfactorily on May 13, 1970. His last proficiency check was conducted on April 11, 1972, and his last line check on August 30, 1972. He completed his last proficiency training on October 27, 1972. His most recent first-class medical certificate was issued without limitation on August 11, 1972.

Captain Whitehouse had accumulated a total of about 18,000 flying hours, of which 2,435 hours were in the Boeing 737. In the 30-day period preceding the accident, he flew a total of 61 hours in the Boeing 737.

First Officer Walter O. Coble, aged 43, was employed by United Air Lines on October 4, 1957. He held Commercial Pilot Certificate No. 1300051, issued on June 30, 1958, with ASEL and instrument ratings. He was qualified as a Boeing 737 first officer on January 31, 1969. On June 19, 1972, he flew an unsatisfactory proficiency check, but passed a subsequent recheck on June 21, 1972. His last proficiency check was conducted on June 21, 1972, and his last line check on October 25, 1972. His most recent first-class medical certificate was issued, without limitation, on July 28, 1972.

First Officer Coble had accumulated a total of about 10,638 hours of flying time, of which 1,676 hours were in the Boeing 737. In the 30-day period preceding the accident, he flew a total of 32 hours.

Second Officer Barry J. Elder, aged 31, was employed by United Air Lines on May 8, 1967. He held Commercial Pilot Certificate No. 1646564 with ASEL and instrument ratings. He was qualified as a Boeing 737 first officer on September 16, 1970, but because of company personnel reductions he reverted to second officer status on the aircraft. He had not received proficiency flight training or recurrent ground training from the company since January 31, 1971. His most recent first-class medical certificate was issued, without limitation, on November 11, 1972.

Second Officer Elder had accumulated a total of 2,683 flying hours of which 1,128 hours were in the Boeing 737. In the 30-day period preceding the accident, he flew a total of 53 hours.

The three flightcrew members had a 23-hour rest period prior to this flight.

APPENDIX B

Marguerite J. McCausland, the first-class stewardess ("A" position), has a seniority date of June 1, 1957. Her initial B-737 emergency procedures training was on March 19, 1968. Classroom and open book recurrent emergency procedures training for the B-737 was conducted on May 17, 1971, and December 20, 1971. Her most recent emergency evacuation training was conducted on a DC-8-62 on May 4, 1972.

D. Jeanne Griffin, coach stewardess ("B" position) has a seniority date of July 5, 1962. Her initial B-737 emergency procedures training was on April 3, 1968. Her most recent B-737 open book and classroom recurrent emergency procedures training was on January 24, 1971, and June 23, 1971. Her most recent emergency evacuation training was conducted on the B-747 mockup on July 27, 1972.

Kathleen S. Duret, coach stewardess ("C" position) has a January 13, 1965, seniority date. Her initial B-737 emergency procedures training was on March 27, 1968. Her most recent classroom B-737 emergency procedures training was on November 30, 1970, and her most recent emergency procedures open book training was on July 13, 1971. Her most recent recurrent emergency evacuation training was conducted on a DC-8-62 on December 6, 1971.

APPENDIX C

AIRCRAFT INFORMATION

Aircraft N9031U, a Boeing 737-222, serial No. 19069, was manufactured in September 1968 and registered to United Air Lines, Inc., on September 26, 1969. A standard airworthiness certificate was issued for the aircraft in September 1968. The aircraft had accumulated a total of 7,247 flying hours at the time of the accident.

Aircraft and component records showed that all inspections and overhauls had been performed within the prescribed time limits and that the aircraft had been maintained in accordance with all company procedures and Federal Aviation Administration regulations. All applicable airworthiness directives had been complied with as of December 8, 1972.

The aircraft was equipped with two Pratt & Whitney JT8D engines. The No. 1 engine, serial No. 655956, had a total of 5,852 hours since overhaul and the No. 2 engine, serial No. 655840, had a total of 6,554 hours since overhaul.

APPENDIX D

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C.

WRECKAGE DISTRIBUTION CHART
UNITED AIRLINES, INC.
BOEING MODEL 737-222, N9031U
ACCIDENT SITE CO-ORDINATES
WEST LATITUDE 87° 42' 54"
NORTH LONGITUDE 41° 45' 51"
CITY OF CHICAGO, ILLINOIS
DECEMBER 8, 1972

LEGEND

1. FIRST EVIDENCE OF HOUSE DAMAGE. SHINGLES FROM FRONT ROOF PEAK ON GROUND. SECOND FLOOR FRONT STORM WINDOW OFF. FIRST FLOOR FRONT PICTURE WINDOW OUTER PANE DETACHED.
2. TREE IN FRONT LAWN EXHIBITED BROKEN BRANCHES AT A HEIGHT OF APPROXIMATELY 18 FEET. TREE HEIGHT APPROXIMATELY 24 FEET.
3. TREE HAD BROKEN BRANCH AT A HEIGHT OF APPROXIMATELY 18 FEET. TREE APPROXIMATELY 20 FEET IN HEIGHT.
4. LEFT ELEVATOR TIP FOUND ON ROOF. NORTHWEST CORNER OF ROOF DAMAGED.
5. NORTHEAST CORNER OF ROOF DAMAGED.
6. NUMEROUS LIMBS OF TREE BROKEN.
7. SECTION OF LEFT HORIZONTAL STABILIZER SKIN, P/N 65-47536-501. SECTION OF LEFT ELEVATOR, P/N 65-47512-3.
8. POLE SNAPPED OFF APPROXIMATELY 3 FEET 6 INCHES ABOVE GROUND. UPPER SECTION ON GARAGE ROOF.
9. POLE SNAPPED APPROXIMATLEY 11 FEET 8 INCHES ABOVE GROUND. UPPER SECTION IN BACK YARD.
   NOTE:
   TELEPHONE CABLE LOCATED 20 FEET ABOVE GROUND LEVEL.
   ELECTRICAL CABLE LOCATED TOP OF POLE.
   POLES MEASURED APPROXIMATELY 34 FEET IN HEIGHT.
   CABLES FAILED IN TENSION.
10. NORTH SECTION OF GARAGE ROOF DAMAGED. GARAGE MOVED OFF FOUNDATION.
11. NORTH SECTION OF GARAGE ROOF CAVED IN.
12. LEFT HORIZONTAL STABILIZER AND ELEVATOR SECTION.
13. SECTION OF RIGHT HAND OUTBOARD MID FLAP.
14. HYDRAULIC LINE AND FITTING.
15. RIGHT WING TIP INCLUDING TANK VENT.
16. SECTION OF LEADING EDGE SLAT, SECTION OF FLAP TRACK, AND TWO FUEL TANK PLATES FOUND IN BASEMENT.
17. SOUTHWEST CORNER OF HOUSE DAMAGED.
18. SECTION OF RIGHT WING LEADING EDGE FOUND BETWEEN HOUSES.
19. SECTION OF LEFT HORIZONTAL STABILIZER.
20. SECTION OF FLAP TRACK INCLUDING JACK SCREW.
21. SECTION OF FLAP TRACK FAIRING.
22. FLAP MID FLAP SECTION AND JACK SCREW.
23. OXYGEN FILLER AND GAUGE.
24. RIGHT HAND STRUT DOOR P/N 65-52202-36.
25. STRUT DOOR P/N 65-52201-88.
26. SECTION OF SKIN WITH STRINGERS, P/N 65-55726-5.
27. SKIN AND RIB SECTION.
28. SECTION OF SKIN WITH LOUVRE.
29. FUEL TANK PLATE, P/N 65-46446-1 (2 EACH).
   NOTE:
   ITEMS 20 THROUGH 29 NOT IN ORIGINAL LOCATION. FOUND IN STREET AND ON SIDEWALK OF LOT 3719 WEST 70th PLACE.

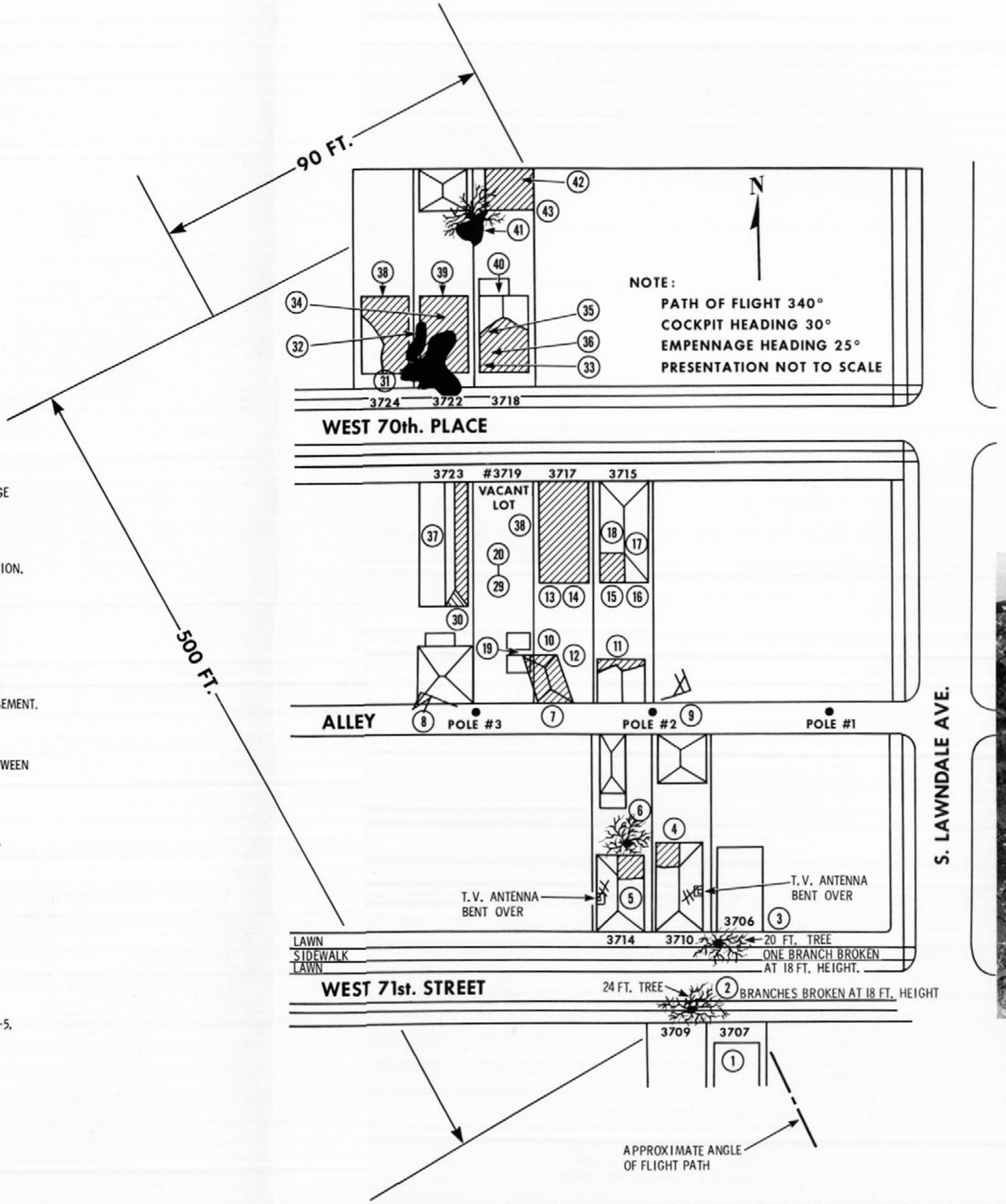

PHOTO "A"

PHOTO "B"

LEGEND

30. NUMEROUS PIECES OF LEFT WING TIP FLASHING LIGHT LENSE.
31. EMPENNAGE SECTION.
32. LEFT ENGINE.
33. RIGHT ENGINE.
34. LEFT WING CENTER SECTION.
35. RIGHT WING CENTER SECTION.
36. OUTBOARD RIGHT WING SECTION.
37. ROOF DAMAGED
38. HOUSE DESTROYED
39. HOUSE DESTROYED
40. HOUSE DESTROYED
41. COCKPIT AREA AGAINST TREE
42. GARAGE DESTROYED
43. RIGHT MAIN LANDING GEAR.

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TRANSCRIPTION OF COCKPIT VOICE RECORDING, UA 553, DECEMBER 8, 1972

LEGEND

CAM	Cockpit area microphone
RDO	Radio transmission from N9031U (UA 553)
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Second Officer
-?	Voice unidentified
9VS	Radio transmission from Aero Commander 680, N309VS
CAPC	Radio transmission from Chicago Approach Control
MTWR	Radio transmission from Midway Tower
*	Unintelligible word/words
#	Nonpertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause

NOTE: All time appears as Greenwich Mean Time (GMT)

INTRA-COCKPIT SOURCE & TIME	CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	CONTENT
2019:30.5 CAM-1	Recorder go off?		
CAM-3	Pardon me:		
		2019:32.0 RDO-2	Ah, Midway approach, United five five three, we're at four thousand, understand it's three one left
CAM-1	Recorder go off?		
CAM-3	Yeah		
CAM-?	* * *		
2019:45.5 CAM-1	See what's wrong with it, will ya?		
		2019:50.0 RDO-2	Do ya read United five five three?

INTRA-COCKPIT

SOURCE & TIME	CONTENT
2020:37.5 CAM-3	Braking action reported fair by a guppy
CAM-1	Fair?
CAM-3	On one, ah, three one left
CAM-3	The only change is the altimeter thirty oh five
CAM-?	* * *
CAM-1	Sounds to me a circuit breaker, perhaps
2020:52.5 CAM-3	Hah?
CAM-?	* * *
CAM-1	Yeah, I just meant, I thought you'd better check everything, ah

AIR-GROUND COMMUNICATIONS

SOURCE & TIME	CONTENT
2019:52.0 CHI APC	Sir, I was busy on that phone over there, you're in radar contact, two ninety heading, intercept thirty-one left localizer for Midway, Oscar's current
2020:00.0 RDO-2	Okay, thank you, we got Oscar, ah, two ninety on the heading --- intercept three one left
2020:04.0 CHI APC	--S, sir
2020:09.0 CHI APC	Nine Victor Sugar radar contact south heading, two thousand five hundred, vector for thirty-one left again
RDO-2	Sound of LOM IDENT ((Kedzie LOM, DASH, DASH, DASH, DOT, DOT, DASH))

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
SOURCE & TIME	CONTENT	SOURCE & TIME	CONTENT
CAM-3	It, ah, -- indicates		
CAM	Sound of several clicks ((appear between words "ah" and "indicates" above)) ((heard on all four tracks sounds similar to circuit breaker deactivated and activated repeatedly))		
CAM-3	A wire on the reel to test		
CAM	Sound of several clicks		
2021:13.0 CAM-3	It tests		
CAM-3	I think it's okay. I think it's working		
CAM-?	* * *		
2021:23.0 CAM-3	It says off		
		2021:23.5 CHI APC	Zero nine VS turn left to one three zero
CAM-1	You got an "off" light		
CAM-3	Yeah, but, ah, the signal, the encode light comes on		
CAM-?	* * *		
CAM-3	And it shows, indicating tape		
CAM	Sound of two clicks ((similar to flap lever movement))		

INTRA-COCKPIT SOURCE & TIME	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	AIR-GROUND COMMUNICATIONS CONTENT
		2021:56.5 CHI APC	United five five three, slow to a hundred an eighty knots
		2021:59.5 RDO-2	Hundred an eighty knots, five five three
2022:00.0 CAM	Sound of two clicks ((similar to flap lever movement))		
		2022:26.5 CHI APC	Zero nine VS, descend to two thousand feet
CAM	Sound of clicks ((similar to electric trim actuator))		
2022:42.5 CAM-2	Wonder why they put that in there, final approach from holding pattern at Kedzie not authorized?		
		2022:45.5 CHI APC	Zero nine VS turn left zero nine zero
CAM-2	What would be wrong if you were there in the holding pattern? You'd be back here anyway		
CAM-2	Wonder why?		
CAM-1	I don't know		
CAM-1	The holding pattern's probably higher than fifteen hundred feet		
CAM-2	That's probably true		
CAM-?	* * *		
CAM-3	Or it's not aligned with the runway		
CAM-2	Yeah		

INTRA-COCKPIT SOURCE & TIME	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	AIR-GROUND COMMUNICATIONS CONTENT
		2023:12.0 CHI APC	Zero nine VS turn left heading zero two zero
		2023:16.0 CHI APC	Five five three, slow to a hundred an sixty knots
		2023:18.5 RDO-2	Hundred an sixty knots, five five three
2023:19.5 CAM	Sound of three clicks ((similar to movement of flap lever))		
		2023:20.0 CHI APC	S, sir, then descent to two thousand feet -- 'nited five five three
		2023:23.0 RDO-2	Down to two thousand -- five five three, leavin' four
CAM	Sound of clicks ((similar to sound of stabilizer trim actuation))		
		2023:35.0 CHI APC	An zero nine VS -- what is your airspeed now?
		2023:39.5 CHI APC	'kay, keep it up for a while, please
		2023:42.0 CHI APC	Five five three start slowin' to yer approach speed, please
		2023:44.5 RDO-2	Okay, slowin' up

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
SOURCE & TIME	CONTENT	SOURCE & TIME	CONTENT
CAM	Sounds of several clicks ((similar to sound of stabilizer trim actuation))		
		2024:08.5 CHI APC	* VS, turn left heading three two zero now, intercept, cleared for the approach, stay with me
2024:31.5 CAM-3	Christ, I can't even find the circuit breaker for this		
CAM-2	Over here		
CAM-?	* * * flight recorder		
CAM-?	* * *		
		2024:44.5 CHI APC	Nine VS, keep as much speed as long as you can sir, call the tower now, one eighteen seven
2024:50.0 CAM-3	I don't know		
CAM-3	Don't know what to say		
CAM-3	I get a reaction when I pull the, ah, AC		
CAM-2	No reaction when you pull the DC though		
CAM-3	You want me to call Maintenance?		
CAM-1	Call it in		
CAM-3	Is this tape? Or uh		
2025:11.5 CAM-3	I'll have to call Dispatch		
CAM-?	* * *		

INTRA-COCKPIT SOURCE & TIME	CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	CONTENT
		2025:25.0 CHI APC	Five five three, call the tower now on one eighteen seven
		2025:28.0 RDO-2	Eighteen seven, five five three
		2025:35.5 RDO-2	Midway tower, United five five three, an' we're out of three for two
		2025:39.0 MTWR	United five five three, report passing the outer marker, number two on the approach
2025:41.0 CAM-3	Chicago, this is five five three ((second officer calling ARINC))		
		2025:44.0 RDO-2	Okay, report the outer marker
2025:46.5 CAM-1	Let's have the gear down please		
		2025:48.0 RDO-1	Start of first sound of first series of Kedzie outer marker beacon tones
2025:50.97 CAM-3	Chicago, United five five three ((second officer calling ARINC))		
2025:51.62 CAM	Sound of a click ((similar to sound of landing gear handle going into down detent))		
CAM	Sound of chime ((simultaneous with click above))		

INTRA-COCKPIT SOURCE & TIME	CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	CONTENT
		2025:52.20 MTWR	Nine Victor Sugar, what's your airspeed?
		2025:54.5	End of sound of first series of Kedzie outer marker beacon tones
		2025:54.74 9VS	Ah, we're down to ah, hundred twenty knots
2025:55.06 CAM	Increase in ambient noise level ((similar to increase made by nose landing gear extended))		
		2025:56.82 MTWR	Ah hundred and twenty, okay
2026:00.64 CAM	Sound of first of four clicks in rapid increase ((sounds similar to flap lever moved from fifteen degrees to 25 degrees position))		
2026:01.50 CAM-?	Gear 'own		
CAM	Sound of several clicks ((similar to sound of stabilizer trim actuation))		
		2026:10.02 RDO-1	Sound of beginning of second series of Kedzie outer marker beacon tones
		2026:20.02 RDO-1	End of sound of second series of Kedzie outer marker beacon tones
2026:24.66 CAM-1	Final descent check		

INTRA-COCKPIT SOURCE & TIME	CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	CONTENT
2026:25.66 CAM-3	Flight and nav		
2026:27.11 CAM-2	Cross-checked		
CAM-?	* * *		
CAM	Sound of clicks ((similar to sound of stabilizer trim actuation))		
		2026:30.62 RDO-2	United five five three, an, ah, Kedzie inbound
2026:35.97 CAM-?	Flight		
		2026:36.38 MTWR	United five five three, continue inbound, you're number two on the approach -- 'll keep you advised
2026:40.10 CAM	Sound of several clicks ((similar to sound of electrical stabilizer trim actuation))		
		2026:40.46 RDO-2	Okay
2026:40.96 CAM-2	Cross-checked		
CAM-3	With a glideslope flag		
CAM-2	No glideslope		
		2026:41.10 9VS	Eh, nine VS has the runway

INTRA-COCKPIT

SOURCE & TIME	CONTENT
2026:44.67 CAM-3	Aaan the --- landing gear
2026:50.41 CAM-2	Down, three greens
2026:51.37 CAM-3	Speed brake?
2026:52.45 CAM-2	Ah --- armed
2026:54.69 CAM	Sound of click ((similar to sound made by moving speed brake lever to armed position))
2026:56.04 CAM-3	Wing flaps
2026:58.75 CAM	Sound of click ((similar to sound made by flap lever moving into detent))

AIR-GROUND COMMUNICATIONS

SOURCE & TIME	CONTENT
2026:43.06 MTWR	Nine VS, runway three one left cleared to land
2026:46.18 9VS	Okay
2026:48.40 MTWR	Nine VS, do ya have the right runway in sight by any chance?
2026:51.37 9VS	Affirmative
2026:52.6 MTWR	'ud you swing over to that and land? There's a jet about two m-- and disregard that, ah, okay, I see ya now, you're cleared to land on thirty-one left

INTRA-COCKPIT SOURCE & TIME	CONTENT	AIR-GROUND COMMUNICATIONS SOURCE & TIME	CONTENT
2026:59.42 CAM-2	Thirty, green light, pressure fluid		
2027:01.48 CAM-3	An the auto-pilot?		
CAM	Sound of click ((similar to electrical stabilizer trim actuation)) simultaneous with "an the auto-pilot"		
2027:02.96 CAM-2	Disarmed		
2027:04.11 CAM-2	Ah thousand feet		
		2027:04.50 MTWR	United five fifty-three, execute a missed approach, make a left turn to a heading of --- one eight zero, climb to two thousand ((between words "of" and "one" there is a pause and a voice in the background says "one eighty."))
2027:05.74 CAM	Sound of stickshaker begins and continues to end of recording		
2027:07.56 CAM-?	((Two to three hurried words at very low amplitude and masked by noise of stick-shaker))		
CAM	Sound of click ((similar to sound made by flap lever moving into detent))		
		2027:12.14 RDO-2	Okay, left turn to one eight zero, --- left turn, okay?

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
SOURCE & TIME	CONTENT	SOURCE & TIME	CONTENT
2027:13.88 CAM-3	Want more flaps?		
2027:15.33 CAM-?	Flaps fifteen		
		2027:15.45 MTWR	Yeah, make left turn to one eighty
2027:16.14 CAM-?	I'm sorry		
2027:16.47 CAM	Sound of click ((similar to sound made by flap lever moving into detent))		
2027:19.4 CAM	Sound of click ((sound similar to landing gear lever moved out of down detent))		
2027:20.14 CAM	Sound of double click ((sound similar to landing gear lever moved into up detent))		
2027:20.64 CAM	Sound of landing gear warning horn begins and continues to end of recording		
2027:23.55 CAM	Sound of initial impact and garbled voice		
		2027:24.46 RDO-1	Sounds of impact and unintelligible voice ((over open microphone))
		2027:25.02 RDO-1	END OF RECORDING

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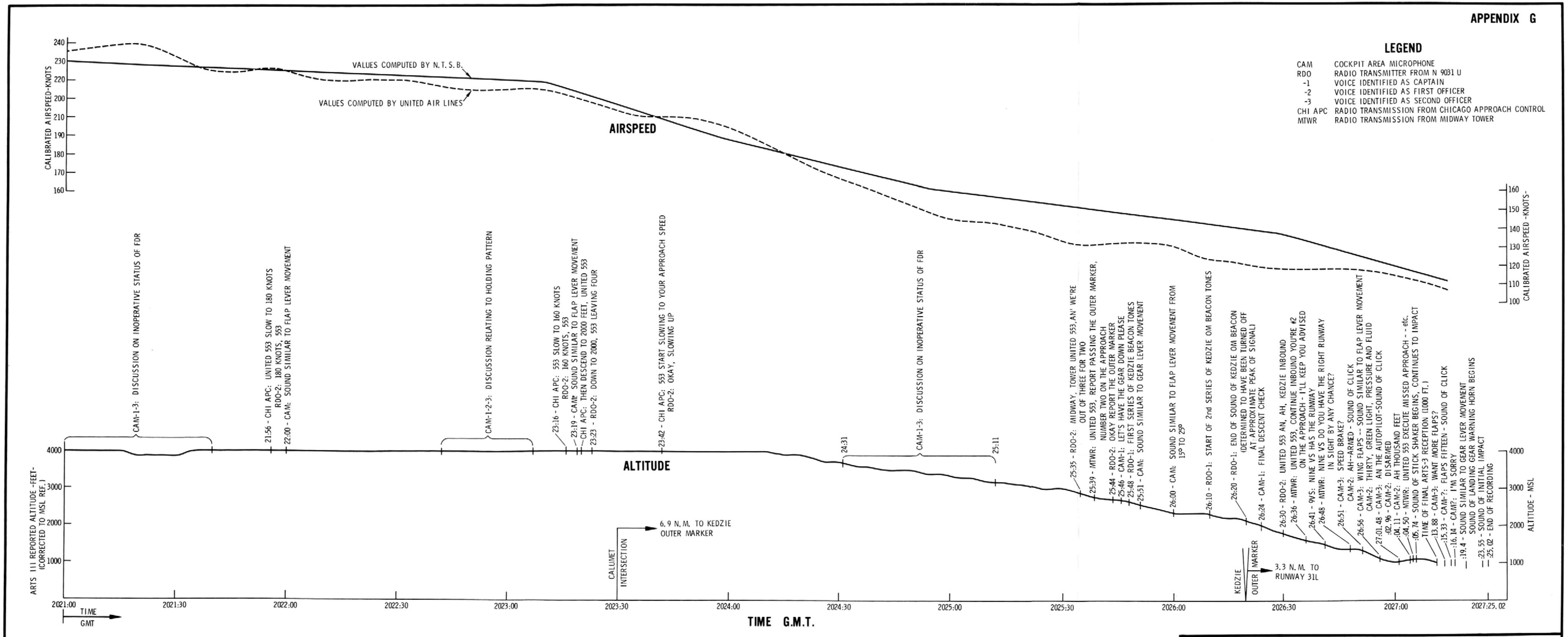
APPENDIX G



NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C.

APPROACH PROFILE DERIVED FROM ARTS III AND CVR DATA
UNITED AIRLINES, INC. B-737, N9031U, FLIGHT 553
NEAR MIDWAY INTERNATIONAL AIRPORT, CHICAGO, ILLLINOIS
December 8, 1972

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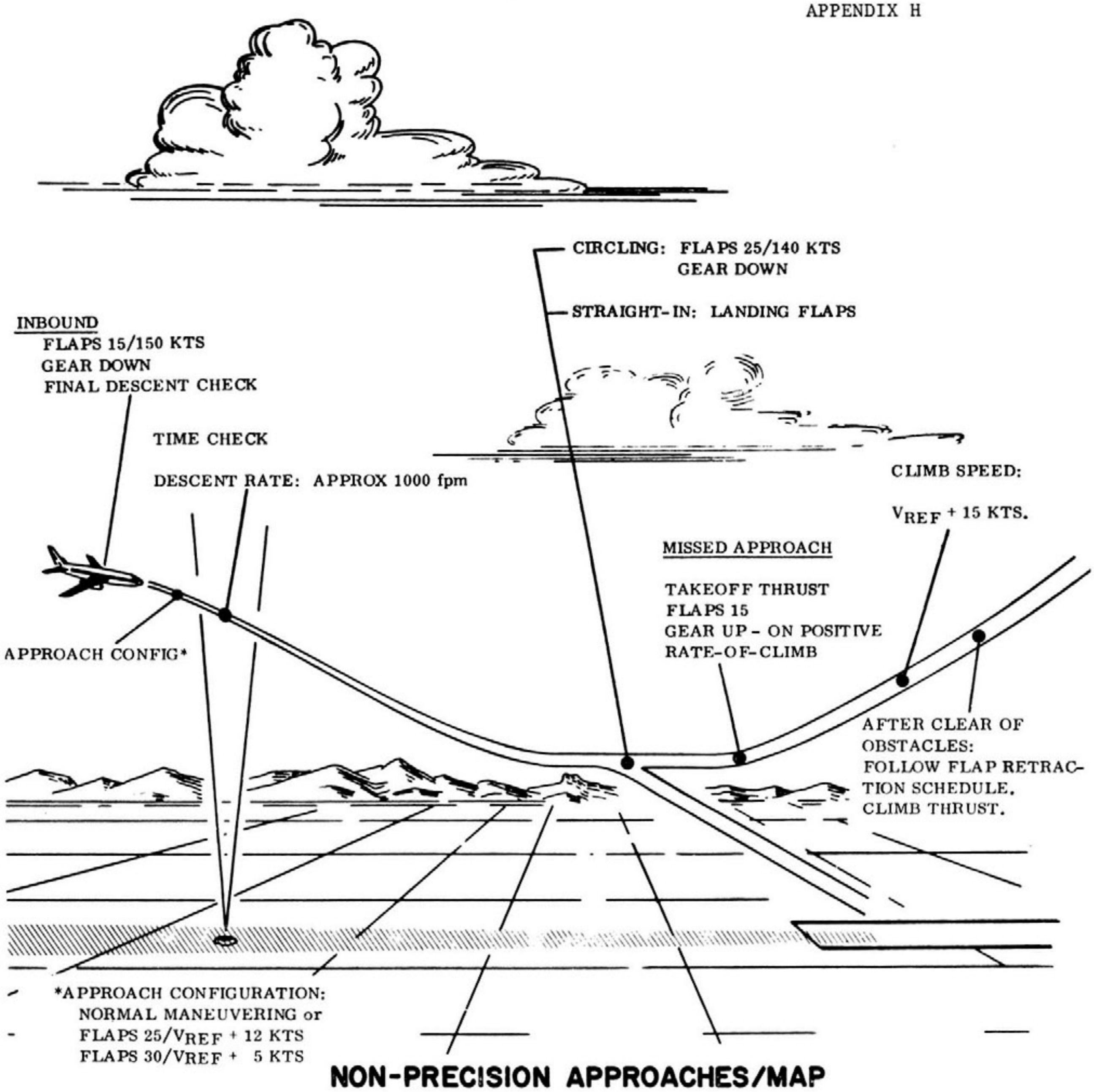

NON-PRECISION APPROACHES/MAP

TWO ENGINES

UNITED STATES OF AMERICA
NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: June 25, 1973

Adopted by the NATIONAL TRANSPORTATION SAFETY BOARD
at its office in Washington, D. C.
on the 6th day of June 1973

FORWARDED TO:
Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATIONS A-73-39 thru 43

The National Transportation Safety Board has under investigation, three accidents involving: a United Air Lines Boeing 737 at Midway Airport, Chicago, Illinois, on December 8, 1972; a North Central Airlines DC-9, at O'Hare International Airport, also at Chicago, Illinois, on December 20, 1972; and an Eastern Air Lines Lockheed L-1011 at Miami, Florida, on December 29, 1972.

The Safety Board has identified several areas in occupant survival and evacuation common to these accidents which it believes merit remedial action by the Federal Aviation Administration. These areas are delineated below:

Shoulder Harness Restraint. Testimony at the Safety Board's public hearing concerning the United B-737 accident revealed that crew takeoff and before-landing checklists did not contain the item "Shoulder Harness Fastened." The injuries sustained by the captain, as well as the conditions of the captain's and first officer's shoulder harness in the wreckage, indicated that the shoulder harness had not been used.

In the EAL accident, we noted that the shoulder harness on the aft facing cabin attendant seats had been removed. In a letter dated March 12, 1973, the Board, in commenting on your Notice of Proposed Rule Making 73-1, expressed its concern about the absence of a requirement to have shoulder harnesses installed on aft facing seats. We pointed out that in crashes or emergency landings involving multidirectional inertia forces, shoulder harnesses would provide an additional, and possibly vital, measure of protection for occupants of aft facing seats. The principal advantage of a shoulder harness, both in forward and rearward facing seats, is that it helps to restrain the user in an upright position, thereby keeping the spinal column in a more suitable position from the standpoint of load distribution. Additionally, the shoulder harness prevents the upper body from flailing, a frequent cause of serious injuries in aircraft accidents. The Board believes that increased protection from injury of the flightcrew as well as the cabin attendants is of vital importance, since their availability to guide and aid passengers during evacuation may make the difference between survival and disaster. Therefore, the Safety Board recommends that the Federal Aviation Administration:

1. Take the necessary steps to ensure that all air carrier before-landing and takeoff checklists contain a "Fasten Shoulder Harnesses" item.

2. Amend 14 CFR 25.785(h) to require provisions for a shoulder harness at each cabin attendant seat, and amend 14 CFR 121.321 to require that shoulder harnesses be installed at each cabin attendant seat.

Auxiliary Portable Lighting. During the investigation and public hearing held in connection with the EAL L-1011 accident, testimony indicated that the absence of lighting of any kind at the crash scene seriously hampered survivors' ability to orient themselves and prevented them from searching for and assisting other injured survivors. Additionally, this lack of light prevented cabin attendants from taking effective charge among the surviving passengers. In both Chicago accidents, a similar lighting problem was encountered. Although section 121.549(b) of the Federal Aviation Regulations requires each crewmember to have available a flashlight, cabin attendants usually stow their personal flashlights in their handbags, which tend to become lost in the debris of the wreckage. This, for example, was the case in both Chicago accidents. The Board believes that effective alternate means of lighting, which is not dependent on random stowage and location, should be readily accessible to the flight attendants. Therefore, the Safety Board recommends that the Federal Aviation Administration:

3. Amend 14 CFR 25.812 to require provisions for the stowage of a portable, high-intensity light at cabin attendant stations; and amend 14 CFR 121.310 to require the installation of such portable, high-intensity lights at cabin attendant stations.

Emergency Lighting. Evidence obtained during the investigation of the North Central DC-9 accident and the United B-737 accident in Chicago, indicated that many passengers had difficulties in escaping from the wreckage. These difficulties were a result of inadequate illumination, combined with a heavy smoke condition in one of these accidents. In the United accident, survivors specifically mentioned the absence of any light in the cabin. In the North Central accident, passengers experienced great difficulty in locating the exits, reportedly because of darkness and heavy smoke in the cabin. Yet, the crew testified that the emergency lighting system was armed, and the investigation indicated that they should have been operational. However, four of the nine fatally injured passengers apparently died while they were attempting to find an exit. One passenger was found in the cockpit, one near the cockpit door, and two others were found near the aft end of the cabin. The five remaining fatalities apparently had not left their seats.

Numerous recommendations and proposals to improve occupant escape capabilities in survivable accidents have been made over the years by various Government and industry organizations; and, indeed, significant improvements have occurred. Unfortunately, however, experience indicates that the existing escape potential from aircraft in which postcrash fire is involved is still marginal. These accidents illustrate the vital role that adequate illumination can play in contributing to such postcrash survivability.

A review of 14 CFR 25.811 and 25.812 indicates that paragraph 811(c) requires means to assist occupants in locating exits in conditions of dense smoke. Yet, information from the Civil Aeromedical Institute in Oklahoma City indicates that the illumination levels specified in paragraph 812 are not predicated on a smoky environment, and therefore may be ineffective under conditions of dense smoke. In order to eliminate this inconsistency, the Board believes that illumination levels should be specified in paragraph 812, which are consistent with the requirements of 14 CFR 25.811(c). Moreover, these and other accident experiences have shown that for various reasons aircraft emergency lighting systems often do not work or are proved ineffective in survivable accidents. Therefore, the Safety Board recommends that the Federal Aviation Administration:

4. Amend 14 CFR 25.812 to require exit sign brightness and general illumination levels in the passenger cabin that are consistent with those necessary to provide adequate visibility in conditions of dense smoke.