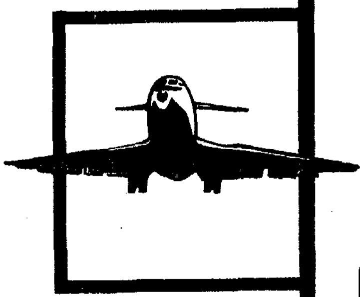

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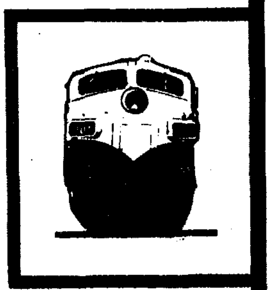

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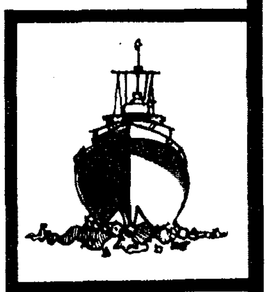
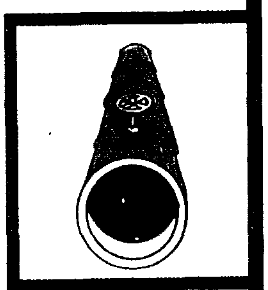


AIRCRAFT ACCIDENT REPORT

COLLISION OF AERONAVES DE MEXICO, S.A. McDONNELL DOUGLAS DC-9-32, XA-JED AND PIPER PA-28-181, N4891F CERRITOS, CALIFORNIA AUGUST 31, 1986



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UNITED STATES GOVERNMENT

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16. Abstract On August 31, 1986, about 1152 Pacific daylight time, Aeronaves de Mexico, S.A., flight 498, a DC-9-32, Mexican Registration XA-JED, and a Piper PA-28-181, United States Registration N4891F, collided over Cerritos, California. Flight 498, a regularly scheduled passenger flight, was on an Instrument Flight Rules flight plan from Tijuana, Mexico, to Los Angeles International Airport, California, and was under radar control by the Los Angeles terminal radar control facility. The Piper airplane was proceeding from Torrance, California toward Big Bear, California, under Visual Flight' Rules, and was not in radio contact with any air traffic control facility when the accident occurred.

The National Transportation Safety Board determines that the probable cause of the accident was the limitations of the air traffic control system to provide collision protection, through both air traffic control procedures and automated redundancy. Factors contributing to the accident were (1) the inadvertent and unauthorized entry of the PA-28 into the Los Angeles Terminal Control Area and (2) the limitations of the "see and avoid" concept to ensure traffic separation under the conditions of the conflict.

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EXECUTIVE SUMMARY

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The collision occurred inside the Los Angeles Terminal Control Area near 6,560 feet mean sea level. At the time of the collision, the sky was clear, and the reported visibility was 14 miles. The air traffic controller providing service to flight 498 did not observe the Piper airplane's radar return on his display and therefore did not provide any traffic advisory to flight 498 concerning the location of the Piper airplane before the collision. Both airplanes fell to the ground within the city limits of Cerritos. Five houses were destroyed and seven other houses were damaged by airplane wreckage and postimpact fire. Fifty-eight passengers and six crew members on the DC-9 were killed; the pilot and 2 passengers on the Piper were killed; 15 people on the ground were killed and 8 others received minor injuries.

The National Transportation Safety Board determines that the probable cause of the accident was the limitations of the air traffic control system to provide collision protection, through both air traffic control procedures and automated redundancy. Factors contributing to the accident were (1) the inadvertent and unauthorized entry of the PA-28 into the Los Angeles Terminal Control Area and (2) the limitations of the "see and avoid" concept to ensure traffic separation under the conditions of the conflict.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: July 7, 1987

MIDAIR COLLISION OF AERONAVES DE MEXICO, S.A., MCDONNELL DOUGLAS DC-932, XA-JED, AND PIPER PA-28-181, N4891F CERRITOS, CALIFORNIA AUGUST 31, 1986

1, FACTUAL INFORMATION

1.1 History of the Flights

On August 31, 1986, about 1141 Pacific daylight time 1/, Piper PA-28-181, N4891F, departed Torrance, California, on a Visual Flight Rules (VFR) flight to Bii Bear, California. The pilot of the Piper had filed a VFR flight plan with the Hawthorne, California, Flight Service Station (FSS). According to the flight plan, his proposed route of flight was direct to Long Beach, California, then direct to the Paradise, California, VQRTAC 2/, and then direct Big Bear. The proposed enroute altitude was 9,500 feet 3/. However, the pilot did not, nor was he required to, activate his fliiht plan. At 1140:36, after being cleared for takeoff, the Piper pilot told Torrance tower that he was “rolling;” this was the last known radio transmission received from the Piper.

According to recorded air traffic control (ATC) radar data, after leaving Torrance, the Piper PA-28 pilot turned to an easterly heading toward the Paradise VORTAC. The on board transponder was active with a 1200 code. Postaccident investigation revealed that as the Piper proceeded on its eastbound course, it entered the Los Angeles Terminal Control Area (TCA) without receiving clearance from ATC as required by Federal Aviation Regulations (14 Code of Federal Regulations (CFR) Part 91.90 [a] [1].)

Aeronaves de Mexico, S.A. (Aeromexico), flight 498, a DC- 9-32, Mexican Registry XA-JED, was a regularly scheduled passenger flight between Mexico City, Mexico, and the Los Angeles International Airport (L.A. International), California, via Guadalajara, Loreto, and Tijuana, Mexico. At 1120:00, flight 498 departed Tijuana with 58 passengers and 6 crew members in accordance with its filed instrument flight rules (IFR) flight plans. As the flight proceeded toward L.A. International, at 10,000 feet, it was handed off to Coast Approach Control, which cleared the flight to the Seal Beach, California, VORTAC, and then to "cross one zero miles southeast of Seal Beach at and maintain seven thousand (feet)." At 1144:54, flight 498 reported that it was leaving 10,000 feet, and, at 1146:59, it was instructed to contact Los Angeles Approach Control.

1/ All times herein are Pacific daylight based on the 24-hour clock.
2/ A collocated very high frequency OMNI range station and ultrahigh frequency tactical air navigation aid providing azimuth and distance information to the user.
3/ All altitudes are mean sea level unless otherwise specified.

At **1147:28,** fliit 498 contacted the Los Angeles Approach Control's Arrival Radar-l **(AR-1)** controller and reported that it was level" at 7,000 feet. **The** AR-1 controller cleared flight 498 to depart Seal Reach on a heading of **320°** for the **ILS** (instrument landing system) runway "two five left final approach course..." Plight 498 acknowledged receipt of the clearance. At **1150:05,** the AR-l controller requested flight 498 to reduce its airspeed to 210 knots indicated airspeed **(KIAS)** and the **flightcrew** acknowledged receipt of the request.

Between **1149:36** and **1149:52,** flight 498 contacted Aeromexico operations at **L.A.** International on the company's radio frequency with its arrival message and the Aeromexico station agent gave the gate assignment to the flight.

At **1150:46,** the AR-l controller advised flight 498 that there was Traffic, ten o'clock, one mile, northbound, altitude **unknown."** **Flight** 498 acknowledged the advisory, but it never advised the controller that it had sighted the **"traffic".** (This radar target was not that of the Piper PA-28.) At **1151:04,** the AR-l controller asked the flight to reduce its airspeed to 190 **KIAS** and cleared it to descend to 6,000 feet. Flight 498 acknowledged receipt of the clearance. At **1151:45,** the AR-l controller asked flight 498 to maintain its present airspeed.

The flightcrew asked the controller what speed he wanted and added that it was *educing to . . . one niner zero." At **1151:57,** the controller told the flight "to hold what you have . . . and we have a change in **plans** for **you."** At **1152:00,** plight 498 stated that it would maintain 190 **KIAS.** At **1152:18,** the AR-l controller advised flight 498 to "expect the ILS runway two four right approach . . ." **flight** '498 did not acknowledge receipt of this message, and the **1152:00** radio transmission was the Iast known communication received from flight 498.

At **1151:18,** after flight 498 was cleared to descend to 6,000 feet, the pilot of a Grumman Tiger **airplane, N1566R,** contacted the AR-l controller. At 115166, after radio contact was established, the Grumman pilot informed the controller that he was on a VFR flight from Fullerton to Monterey, California, via the Van Nuys, **California,** VORTAC, that his requested en route altitude was 4,500 feet, and that he would like ATC flight following services. **The** AR-l controller did not answer this transmission until **1152:04** when he requested the pilot to set his transponder to code 4524, a discrete transponder code within the 4500 series used by approach control for VFR flights. At **1152:29,** the controller asked the Grumman pilot if he was at **4,500** feet and the pilot answered that he was climbing through 3,400 feet. At **1152:36,** the AR-l controller told the Grumman pilot that he was in the middle of the TCA and suggested that **"in** the future you look at your TCA chart. You just had an aircraft pass right off. your left above you **at** five thousand feet and we run a lot of jets through there right at thirty-five hundred."

The AR-l controller testified that about **1152:36** he **also** noticed that the ARTS III computer was no longer tracking flight 498. After several unsuccessful attempts to contact flight 498, he notified the arrival coordinator that he had lost radio and radar contact with the flight.

At about **11:52:** 09, flight 498 and the Piper collided over Cerritos, **California,** at an altitude of about 6,560 feet. **The** sky was clear, the reported visibility was 14 miles, and both airplanes fell within the city limits of Cerritos. Fifty-eight passengers and **6** crewmembers on flight 498 were **killed** as were the pilot and 2 passengers on the Piper. **The** wreckage and postimpact fires destroyed five houses and damaged seven others. Fifteen persons on the ground were killed and others on the ground received minor injuries. The coordinates of the main wreckage site were **33° 52'N** latitude and **118° 03' "W** longitude.

1.2 Injuries to Persons

	Crew	Passengers	Other	Total
Fatal	7*	60**	15	82
Serious	0	0	0	0
Minor	0		8	8
None	0	8	0	0
Total	7	60	23	90

*Includes the pilot of the Piper PA-28
**Includes the passengers on the Piper PA-28

1.3 Damage to the Airplanes

The DC-g-32 was destroyed by the collision, ground impact, and postimpact fire. The Piper PA-28 was destroyed by the collision and ground impact. The estimated values of the Piper and the DC-9 were $28,000 and $9,500,000, respectively.

1.4 Other Damage

Five houses were destroyed and seven others were damaged by airplane wreckage and/or postimpact fires.

1.5 Personnel Information

The flightcrew and cabin crew of flight 498 were qualified in accordance with applicable Mexican, United States, and company regulations and procedures. The examination of the training records of the Aeromexico crew members did not reveal anything extraordinary (appendix B). Further, the investigation of the background of the flightcrew and their actions during the 2 to 3 days before the accident flight did not reveal anything remarkable.

The air traffic controllers who provided ATC services to flight 498 were qualified in accordance with current regulations. The examination of their training records did not reveal anything extraordinary (appendix B). In addition, the investigation of these controllers' background and their activities during the 2 to 3 days before reporting for duty on August 31 did not reveal anything extraordinary (appendix B).

The pilot of the Piper PA-28 was qualified in accordance with applicable United States regulations (appendix B.) During the investigation, the Safety Board interviewed persons who had flown with the pilot of the PA-28, as well as his flight instructors. Friends, relatives, and colleagues who had flown with the Piper PA-28 pilot described him as a conscientious and careful pilot. One friend said that he was "old maidish" with his preflight checklist, sometimes "too careful" about rules, and aware of his "low-time" experience as a pilot.

The Piper pilot's primary flight instructor stated that he had been a diligent and attentive student. He said that he had taught the Piper pilot to scan for other airplanes by starting his scan pattern "at the left, scan, look at instruments, scan to the right, look at instruments," and then repeat the procedure. He stated that the Piper pilot was familiar with the airplane% wing leveler equipment and that he used the wing leveler "as it was intended" to be used when looking at maps, reviewing charts, or doing other in-cockpit activities.

Another flight instructor who had provided instrument flight training to the Piper pilot stated that they had discussed and used sectional charts during training and that the training had included the numbers used on these charts to show the floor and ceiling altitudes of a TCA. He said the Piper pilot was familiar with VFR hemispherical altitudes, 4/ that he was a "VFR pilot who liked to look out," and that he was more inclined to navigate by visual reference to the ground than by use of navigational radio aides. The flight instructor also stated that he and the Piper pilot had discussed TCAs and other types of restricted airspace, the equipment requirements for flying within restricted airspaces, and the arrival and departure procedures used in the Los Angeles area.

The Piper pilot had moved to Los Angeles from Spokane, Washington, in October 1985. On December 14, 1985, he received Los Angeles area familiarization training and flew an area familiarization flight with a flight instructor. In March 1986, he flew his airplane, N4891F, from Spokane to Los Angeles. Since December 1985, he had flown seven flights in the Los Angeles area and had logged about 5.5 hours on these flights.

1.6 Airplane Jnformation

The DC-932, XA-JED, was owned and operated by Aeromexico. Examination of the DC-9's flight and maintenance logbooks did not reveal any airplane discrepancies or malfunctions that would have contributed to the accident. Examination of the flight's dispatch documents showed that the airplane was operating within its allowable weight and balance limitations. The DC-9 was treated aluminum with orange and blue trim.

The DC-9 had nose gear landing and taxi lights; one wing landing light in each wing; anti-collision lights on top and bottom of the fuselage; ground floodlights in the left and right side of the fuselage; and wing and nacelle flood lights on the left and right sides of the fuselage. In accordance with company procedures, except for the nose gear landing light, all lights are turned on when the airplane is below 10,000 feet.

The Piper PA-28-181, N4891F, a single engine fixed landing gear type airplane, was owned by the pilot involved in the accident. Rxamination of the airplane's flight, maintenance, and engine logbooks did not reveal any discrepancies that would have contributed to the accident. Reconstruction of the airplane's fuel, baggage, and passenger seating locations on the accident flight showed that N4891F was operating within its allowable weight and balance limitations. N4891F was equipped with a NARCO Model AT-50A transponder without a mode C altitude encoder. Given this transponder configuration, N4891F could provide position but not altitude information to Los Angeles Approach Control. The evidence showed that the transponder was functioning properly during the accident flight.

N4891F was painted white with a double yellow stripe running longitudinally along the fuselage. The registration number was blue and there were blue stripes on the wheel pants. N4891F was equipped with navigation lights, a white anticollision strobe light on each wingtip, a rotating red beacon atop the vertical stabilizer, and a landing light on its nosegear. All the light switches were found in the "on" position in the airplane wreckage.

4/ Pursuant to 14 CFR Part 91.109, each person operating an aircraft under VFR in level flight more than 3,000 feet above the surface and below 18,000 feet shall maintain the following altitudes : on a magnetic course of zero° through 179°, any odd mean seal level (MSL) altitude plus 500 feet (such as 3,500, 5,500); on a magnetic course of 180° through 359°, any even thousand feet MSL altitude plus 500 feet (such as 4,500, 6,500).

N4891F was equipped with an Autocontrol IIIB autopilot, which is also called a "wing leveler." The autopilot was a lateral control system, which provided only roll control inputs to the airplane's controls. The airplane would hold a selected heading when the autopilot's heading switch was engaged. The autopilot did not incorporate a radio coupler and, therefore, the airplane could not fly with reference to a radio defined course. The position of the autopilot's control switches could not be determined during the postaccident investigation.

Flight simulations were conducted during the investigation to determine N4891F's climb performance. A Piper PA-28-181, N4305V, configured similary to N4891F on the accident flight, was flown from Torrance Municipal Airport toward the location of the collision using three different climb speeds: 76 KIAS, 80 KIAS, and 85 KIAS. N4305V reached the accident location and 6,500 feet in 11 minutes 31 seconds, 11 minutes 30 seconds, and 11 minutes 45 seconds, respectively. On the day of the simulation, the temperatures aloft were almost identical to those recorded on the day of the accident; the speed of the winds aloft were negligible from the surface to 7,000 feet, whereas on the day of the accident the Piper may have had about a O-knot tailwind component between about 5,300 feet and 6,500 feet.

1.7 Meteorological Information

The terminal forecast for LA International, issued by the National Weather Service (NWS) Los Angeles Forecast Office at 0818, August 31, 1986, and valid from 0900 August 31, to 0900 September 1, stated in part that after 1100 on August 31, the weather would be clear. Infrared photographs taken by the Geostationary Operational Environmental Satellite (GOES) at 1031 and 1131 on August 31 did not show any clouds over the land areas of southern California.

The 1146 surface weather observation at Fullerton Airport (about 4 miles east of the accident site) stated in part that the weather was clear and the visibility was 15 miles. The 1149 surface weather observation at Long Beach Airport (about 6 miles southwest of the accident site) stated in part that the sky was clear and the visibility was 15 miles. The 1150 surface weather observation at L.A. International (about 18 miles west of the accident site) stated in part that the sky was clear and the visibility was 14 miles.

San Diego, California, was the closest point to Los Angeles where NWS upper air sounding data were available. The 0400 San Diego sounding showed a strong subsidence inversion 5/ with a base at 1,925 feet and a top at 3,102 feet; the atmosphere was dry above the inversion. The 1600 sounding also showed the subsidence inversion. The base was at 2,122 feet, the top at 3,070 feet, and the atmosphere was dry above the inversion.

At the time of the accident, the elevation of the sun was 61° 55' above the horizon with an azimuth (bearing from true north) of 148°. This is computed from 34° 0' N latitude, 117° 56' W longitude.

1.8 Navigational Aids

There were no known navigational aids difficulties.

5/ Temperature normally decreases with increasing altitude. An increase in temperature with altitude is defined as a temperature inversion. A subsidence inversion is a temperature inversion produced by the warming of a layer of subsiding (descending) air.

1.9 Communications

There were no known communications difficulties.

1.10 Aerodrome Information

Torrance Municipal Airport, elevation 101 feet, is 3 miles southwest of Torrance, California. The airport is served by two runways: 29L/11R, and 29R/11L. The Piper PA-28 departed from runway 29R, which is 5,000 feet long and 150 feet wide.

Los Angeles International Airport (LA. International), elevation 126 feet, is served by two pairs of parallel runways; runways 25L/7R and 25R/7L are on the south side of the airport's terminal complex, and runways 24L/6R and 24R/6L are on the north side. Runways 25L, 25R, 24L, and 24R are served by ILS approaches.

L.A. International is located near the center of its TCA. Except for a triangular segment in the vicinity of Long Reach, California, the apex of which extends northward from its southern boundary, the TCA is essentially a parallelogram. Its western and eastern boundaries are about 20 nmi and 25 nmi, respectively, from the western edge of L.A. International. The TCA's northern and southern boundaries are essentially parallel to the extended centerlines of L. A. International's four runways and are each about 10 nmi from the center of the airport, respectively. (See figure 1.)

Vertically, the TCA resembles an "upside down" wedding cake, beginning at the surface at L.A. International and rising to a ceiling of 7,00 feet. Proceeding westward from the airport and aligned with the extended centerlines of the airport's runways, the floor of the TCA remains at the surface. Between 11 nmi and 20 nmi west of the airport, the floor rises to 2,000 feet. A similar gradient exists along the eastward extensions of the four runway centerlines. To the north and south of the airport and the extended centerlines of the four runways, the floor of the TCA rises sharply. (See figure 1.)

The lateral and vertical dimensions of the Los Angeles TCA are depicted on the Los Angeles VFR Terminal Area Chart. On one side of the chart, the TCA is superimposed on a Lambert Conformal Conic Projection map (figure 1); the chart's overleaf contains a Charted VFR Flyway Planning Chart of the TCA (figure 2). In addition to depicting the numerous airports in the Los Angeles area, the plan view also depicts prominent landmarks within and adjacent to the TCA. For example, the planning chart shows that Disneyland and the Anaheim Stadium are just east of the TCA's eastern boundary. It also depicts and names the freeways located within and around the TCA. Finally, the planning chart depicts the northsouth VFR flyway over L.A. International and the altitudes to be flown when using this flyway (figure 2).

The TCA charts show that Torrance Municipal Airport is under the southern edge of the TCA and that the floor of the TCA above the airport is 5,000 feet. The Piper pilot bought a Los Angeles Sectional Chart and a Los Angeles VFR Terminal Area Chart on the morning of the accident. The Terminal Area Chart, folded to display the combined map and TCA diagram, was found in the Piper's cockpit wreckage; course lines had not been drawn on either side of the chart.

1.11 Flight Recorders

The Piper PA-28 was not equipped with nor was it required to be equipped with flight recorders.

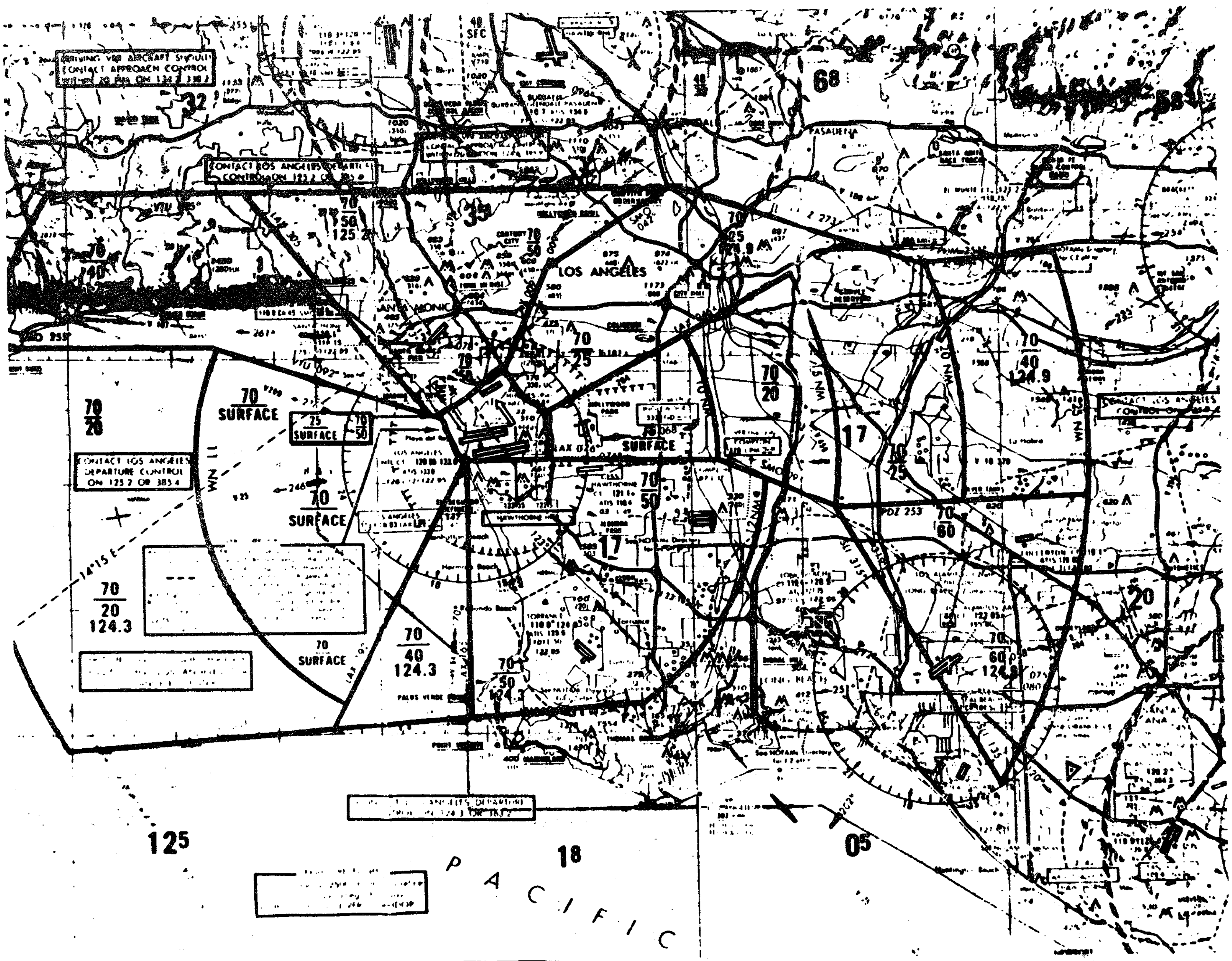


Figure-1.--Los Angeles Terminal Control Area (TCA).

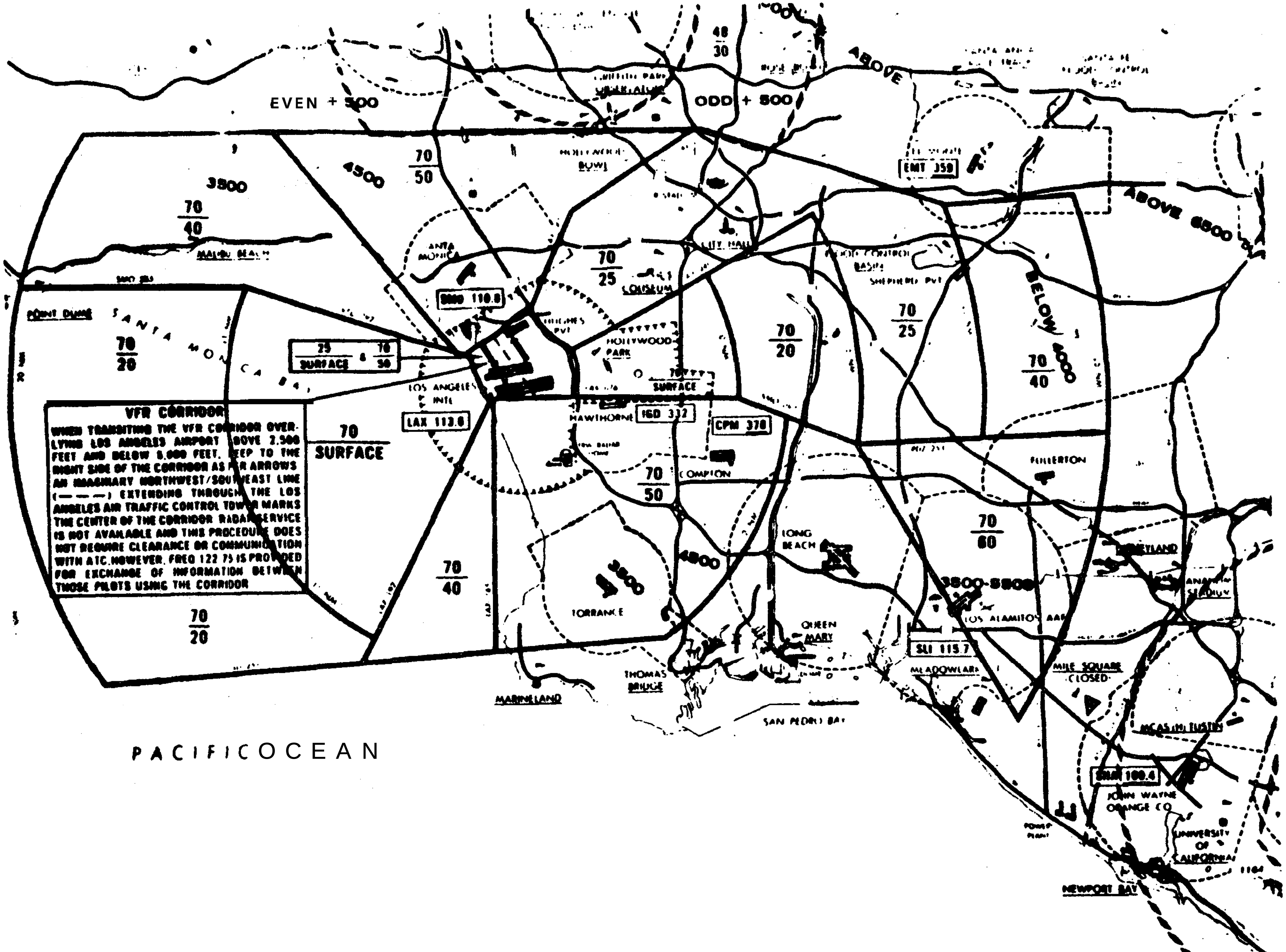


Figure -2.--Charted VFR Flyway Planning Chart of the TCA.

The DC-932 was equipped with a Sunstrand model F-542 Flight Data Recorder (FDR), serial No.5818, and a Sunstrand model V-557 Cockpit Voice Recorder (CVR), serial No. 1829. Roth recorders were brought to the National Transportation Safety Board's flight recorder laboratory in Washington D.C. for examination and readout.

The FDR had been damaged mechanically and by fire. Examination of the foil magazine and the foil recording medium showed that the foil had been torn through, was discolored from intense heat, and that all recorded traces were faint because of improper stylus pressure. The faint traces and the heat discoloration made the recorded traces difficult to read.

The DC-9's latest FDR calibration data sheet was dated February 9, 1983, and these data were used during the readout of the FDR's foil. As a result of inconsistencies in the recorded altitude data, adjustments were incorporated to obtain actual altitude values. The field elevation at flight 498's previous departure point, Tijuana, was 499 feet and the FDR's indicated altitude at Tijuana was -8 feet; therefore, a correction of 507 feet was added to the altitude data and the barometric pressures at Tijuana and Los Angeles were assumed to have been 29.97 in Hg. No other corrections were made to any of the other recorded parameters and a readout of the last 9 minutes of the flight was made, a graphic display of which is appended to this report (appendix C).

During the investigation, the Safety Board's Performance Group used the recorded ATC radar data to reconstruct flight 498's ground speed and indicated airspeed, which they compared to the indicated airspeed recorded by the FDR. The FDR-indicated airspeeds were about 25 KIAS to 30 KIAS faster than the indicated airspeeds derived from the recorded radar data. The Safety Board believes that the indicated airspeeds derived from the radar data are more accurate; therefore, 25 KIAS to 30 KIAS should be subtracted from the FDR indicated airspeed.

The CVR was damaged slightly by impact forees and heavily by the post-impact fire. The CVR tape was not damaged physically and received only minor heat damage. The CVR recording started about 1122:17, just after the engines were started at Tijuana. The Safety Board CVR Group listened to the entire 30-minute recording and a verbatim transcript was made of the last 11 minutes of the flight. The verbatim transcript begins at 1141:21 when flight 498 was level at 10,000 feet and in radio contact with Coast Approach Control. The transcript continues to the end of the recording at 1152:32. The flightcrew's primary language for all intracockpit conversation and for the radio calls to the company was Spanish. All ATC radio calls were in English. Identification of the crewmembers' voices was made by members of the CVR Group, who were familiar with the captain and first officer.

The quality of the entire recording was consistently poor. The sound on the cockpit area microphone (CAM) channel was extremely distorted, and it faded in and out randomly. The distortion and noise were so evident that the CVR Group found it very difficult to understand the intracockpit conversation. This difficulty was exacerbated by the flightcrew's use of the cockpit's overhead speakers to receive ATC communications. Since these speakers are very close to the CAM, the large number of radio transmissions in the Los Angeles area, coupled with the loud volume of the radios, also impaired the intelligibility of cockpit conversation recorded by the CAM.

The poor quality of the CVR recording was not caused by either impact or fire damage. This model CVR has a history of tape tension and recording quality problems. Random storage of the tape causes permanent creases in the recording tape because it folds in the same places many times as it is pushed into the storage sleeve. In addition, if the pressure pad is not set to provide the proper tension, the tape rides up on the record head as it is pulled up by the capstan, and the quality of the recording can be degraded.

Because of the poor quality of the CVR recording; it was necessary to include ATC transmissions from the ATC transcripts to enhance the intelligibility of the CVR transcript. The selected ATC transmissions were checked against the CVR recording to verify that the selected transmissions were broadcast from the overhead speakers. Only those verified ATC transmissions were included in the appended 11 minute CVR transcript (appendix D).

The CVR transcript showed that the flightcrew received the LA International Automated Terminal Information Service (ATIS) message at 1146:46. Thereafter, the flightcrew began to prepare for landing and the intracockpit conversation relating to these tasks ends at 1148:16 when the first officer said, "Flight director up," in response to the captain's challenge.

Between 1148:16 and 1152:10, six transactions were recorded by the CAM. At 1148:31, an unintelligible word was recorded; at 1149:41, a tone was recorded; at 1150:05, an unintelligible female voice was recorded; at 1151:20, an unintelligible word was recorded; at 1151:30, the captain said, "Thank you;" and, at 1152:10, the captain said, "Oh, thii can't be." The 1152:10 remark was the last known remark made by either the captain or first officer.

The CVR recording ended at 1152:32. Between 1152:10 and 1152:32, three ATC broadcasts were recorded, one of which was addressed to flight 498. At 1152:18, the AR-l controller advised the flight that its landing runway was being changed to runway 24R; the flightcrew did not respond to this transmission. With regard to air-to-ground radio communications, the captain made all radio transmissions from flight 498 to ATC facilities.

1.12 Wreckage ad Impact Information

The main wreckage sites of both airplanes were within the city limits of Cerritos and within 1,700 feet of each other.

Piper PA-28-181, N4891F--Except for the upper portion of the fuselage cockpit assembly, engine, vertical stabilizer, and instrument panel, the Piper remained relatively intact after the collision. The major portion of the Piper crashed in an open schoolyard and did not catch fire after impact.

The engine of the Piper PA-28 separated from the fuselage and was found in the yard of a residence about 1,650 feet north of the Piper's main wreckage site. The engine had been damaged extensively by impact forces. Inboard of the No. 3 cylinder, there was a 3 by 6-inch hole in the top of the engine case. A 5 by 8-inch piece from the. upper vertical stabilizer of the DC-9 was lodged in this hole.

The propeller had separated from the engine. One propeller blade had broken off about 18 inches from the propeller hub. This blade was bent aft and was gouged and damaged heavily in the area of separation and on its leading edge. About 6 inches of the tip of the opposite blade had broken off. The remainder of this blade was bent aft and its leading edge in the mid-span area had been damaged by impact forces.

Roth wings were attached to the fuselage and their undersides were buckled. The top of the right wing was relatively undamaged. The top of the left wing had numerous large deep gouges, scratches, and orange paint marks extending from the outboard bulkhead to the wingtip. The gouges, scratches, and paint transfers were aligned at a 30° angle from the wing's leading edge.

The aft section of the fuselage separated just behind the cockpit assembly aft bulkhead, but it remained attached to the forward portion by control cables and the battery shelf attachments. The roof and upper portion of the cockpit assembly was severed from the lower portion of the cockpit assembly along the bottoms of the cockpit assembly windshields and side windows. The separation extended from the engine firewall aft to the cockpit assembly's aft bulkhead.

The entire vertical stabilizer and rudder separated from the fuselage. However, except for a small aft section of the vertical stabilizer, these pieces were recovered. Most of the recovered pieces were buckled and torn severely. The lower portion of the vertical stabilizer's leading edge was dented, distorted, and torn by the impact force.

The stabilator remained attached to the fuselage. The right stabilator was not damaged by impaat forces; however, the leading edge of the left stabilator was dented about 18 inches inboard of its outboard tip rib.

The nose landing gear separated from the airplane. The strut tube had broken in a rearward direction about 8 inches above the towing block.

The servo clutch of the Piper's auto control system (wing leveler) was disengaged; however, the clutch is designed to disengage when electrical power to the system is removed.

Examination of the airplane's altimeter showed that its 100-foot, 1,000-foot, and 10,000-foot pointer assemblies were missing, and that its barometric gear train was moved easily with light finger pressure. Paint transfers similar to the paint used on altimeter pointers were found on the dial face (needle slapping) and the "slap" marks corresponded to the 6,560-foot position on the altimeter dial.

The airplane's radios and transponders were recovered by outside personnel and were delivered to the wreckage collection site in the schoolyard adjacent to the Piper's main wreckage site, where they were examined by team members. The following pertinent readings were observed:

The transponder was set to code 1200.

The No.1 navigational radio was tuned to 115.7 Mhz; this was the published radio frequency of the Seal Reach VORTAC. The OMNI Bearing Selector (OBS) was sot on 0913

The No.2 navigation radio was tuned to 112.2 Mhz; this was the published radio frequency of the Paradise VORTAC. The OBS was set on 0679

DC-9-32 - The majority of the DC-9% wreckage fell within an area about a 600 feet long by about 200 feet wide. The wreckage in this area had disintegrated and was extensively burned. The largest piece of wreckage was a section of the lower aft fuselage. Both engines were found in this area and examination of their rotating components showed that both were operating at high power at impact.

Collision damage on the DC-9 was confined to the vertical and horizontal stabilizers. Pieces of the vertical stabilizer were scattered throughout the wreckage area. Pieces from the upper part of the vertical stabilizer were found near the Piper's wreckage. Most of the pieces from the lower part of the vertical stabilizer were in the DC-9's main wreckage site.

Pieces broken from the upper part of the vertical stabilizer's leading edge were positioned in their normal relative locations to each other. Examination of the repositioned area disclosed a propeller slice, which began about 20 inches below the top of the vertical stabilizer and was about 7 inches left of the airplane% centerline. The plane of the slice was almost parallel to the longitudinal axis of the DC-9.

Recovered sections of skin from both sides of the vertical stabilizer were examined. There was no evidence of impact damage on skin sections from the right side of the stabilizer; however, some of skin areas from the left side had blue paint transfer and tire marks. The blue paint color was consistent with the paint on the nosewheel fairing of the Piper. The smear marks extended aft and upward at a 28° angle relative to the rear spar of the vertical stabilizer and the marks were continuous with smear marks on the left side of the rudder. A gouge on the left side of the rudder extended upward at an angle of 28° relative to the rudder's front spar. The end of the gouge crossed the top of the rudder about 30 inches aft of its front spar and all of the rudder's support hinges were fractured.

The horizontal stabilizer separated during the collision and descended intact to a location about 1,700 feet east of the DC-9's main wreckage site. The leading edge of the horizontal stabilizer left side was crushed, battered, and torn in several areas. The damage began about 1 foot outboard of the vertical stabilizer and extended to a point about 13 feet outboard of the vertical stabilizer. Human remains, debris from the fuselage skin, and insulation from the upper right area of the Piper cabin just aft of the main door frame were embedded in this area of the DC-9's horizontal stabilizer. In addition to the damage described above, the left side of the horizontal stabilizer was scratched and was smeared with white paint consistent in color with that of the Piper. The scratches swept back from the leading edge at a 15° angle relative to the front spar of the horizontal stabilizer. Yellow and blue paint smears were also found at the outboard end of the left horizontal stabilizer.

The horizontal stabilizer's right side leading edge was crushed, but less than the leading edge of the left side of the stabilizer. Between 20 and 40 inches to the right and outboard of the vertical stabilizer, the lower surface of this leading edge was crushed and sliced consistent with damage resulting from a propeller strike. The line defined by the slice swept back at an angle of 29° relative to the front spar of the horizontal stabilizer. Outboard of this damage, there were yellow paint smears and scratches on the right horizontal stabilizer. The yellow paint color was consistent with the Piper's yellow paint and the scratch marks swept back at a 35° angle relative to the front spar of the horizontal stabilizer.

1.13 Medical and Pathological Information

The captain and first officer of the DC-9 were killed by the ground impact forces involved in the accident. Their bodies were fragmented too severely to permit either an autopsy or toxicological test to be performed. The passengers and cabin crew members on the airplane received multiple blunt force trauma injuries from the impact forces and were burned in the postcrash fire.

The pilot and two passengers in the Piper were found in the remains of the airplane's cabin; they were strapped in the left front seat, the right front seat, and the right rear seat. All three occupants had been decapitated.

An autopsy was performed by the Los Angeles County coroner on the pilot of the Piper. With regard to the pilot's general medical state, the medical examiner found "generalized arteriosclerosis, slight to moderate and coronary arteriosclerosis, moderate to focally severe with complete proximal occlusion of the main right coronary artery." The autopsy report issued by the Coroner of Los Angeles County ascribed the death of the pilot of the Piper to "multiple injuries due to or as a consequence of blunt force."

The Armed Forces Institute of Pathology (AFIP) also reviewed the autopsy protcol and the heart of the pilot of the Piper. With regard to their examination of the pilot's heart, the AFIP pathologists found severe coronary atheriosclerosis but "no necrosis or other evidence of acute myocardial infarction identified."

Toxicological tests conducted during the postmortem examination of the Piper pilot were negative for drugs and alcohol. The carbon monoxide saturation level was well below the levels required to produce incapacitation.

The AR-l controller agreed to and, on September 2, 1987, was tested for the presence of drugs and alcohols; both tests were negative.

1.14 Fire

The DC-g-32 caught fire after it struck the ground. The postimpact fire contributed to the destruction of the airplane. The Piper PA-28 did not catch fire either in flight or after it struck the ground.

1.15 Survival Aspects

The DC-932 was configured for a two-man flightcrew and 115 passengers. Passenger scats were arranged into 23 rows of two seats located on the left side of the cabin and 23 rows of three seats located on the right side of the cabin. A double aft-facing flight attendant seat was in the forward cabin near the main cabin door; another double forward-facing flight attendant seat was located on the cabin's aft bulkhead. The entire cockpit and passenger cabin area of the DC-9 was destroyed by impact forces and subsequent fire. Only one passenger seat was found intact; it had been thrown clear of the fire and had penetrated a garage door.

The cockpit-cabin area of the Piper PA-28-181 was configured with side-by-side pilot seats and side-by-side passenger seats aft of the pilot seats. The roof of the cockpit-cabin area was torn from the airplane and found away from the remainder of the fuselage.

The accident occurred a considerable distance from any major airport and thus response to the scene was the responsibility of municipal fire departments and law enforcement agencies. Examination of the response times of these agencies showed that they arrived at the accident scene promptly. For example, one Los Angeles County Fire Department engine company received the alarm at 1153; at 1154, the engines were dispatehed; and at 1158, the engines arrived on the scene.

L16 **Tests and Research**

1.16.1 **Visibility and Vision** studies

A visibility study was conducted to determine the physical limitations to visibility from the pilot and copilot seats of the DC-932 and from the Piper PA-28-181. To accomplish this, the time histories of both airplanes' flightpaths and attitudes, as contained in the radar track plot, and the performance information on flight 498's FDR were combined with binocular photographs 6/ of the respective cockpits. The viewing angles for each airplane were then calculated and plotted at 5-second intervals in relation to the design eye reference (DER) points for each airplane's windshields (appendix E). The study showed that between 1150:56 and 1152:01, the Piper was about 15° to 30° left of the DER point on the captain's windshield and between 15° to 30° left of the DER point on the first officer's windshield. For the first officer, assuming that he did not move, the Piper airplane was located on the airplane% center windshield and in an area where, for about 50 percent of the time, he could see it with both eyes. Assuming the captain did not move, the Piper was located primarily in an area where he could see it with both eyes.

With regard to the Piper pilot, between 1150:56 and 1152:01, the DC-9 was about 50° to the right of the DER point and could only be seen by him on the far right side of the copilot's windshield. For someone seated in the Piper's right seat, the DC-9 was about 55° to the right of the DER point on the right windshield and, assuming no repositioning of the head, would have appeared at the left edge of the right side window. However, neither of the two passengers on the Piper had received any type of aviation or scan training.

L16.2 **Target Acquisition** Performance

The ability of pilots to sight other airplanes in flight was evaluated during two test programs conducted by the Lincoln Laboratories of the Massachusetts Institute of Technology (MIT). These tests were part of a general research project and were not conducted as a result of this accident. In addition to counting the number of times that these pilots either acquired or failed to acquire an intruder airplane visually, the tests determined the distance at which the targets were acquired.

One test evaluated pilot performance during unalerted search. The tests were conducted during a series of triangular round robin flights from Hanscom Field, Massachusetts, using two VORTACS near, but not inside, the Boston TCA as waypoints. The subject pilots were not alerted that there would be intruder aircraft or that scanning behavior was the focus of the study. Each leg was flown at a different altitude and the pilot was required to perform his own navigation and answer various questions asked by the evaluator during the flight. The planned angles of the intercepts were head-on, 90°, and 135°, and the intercepts were predominantly from the left (the pilot's side of the airplane). Data were obtained for 64 unalerted encounters. Visual acquisition was achieved in 36 encounters (56 percent of the total), and the median acquisition range for these 36 encounters was .99 nmi. The greatest range of visual acquisition was 2.9 nmi.

The other test program evaluated the performance of pilots who had been alerted to the presence of an intruder airplane. Data for 66 encounters were collected during the testing of the TCAS IL The subject pilots were aware that intercepts would be conducted and they received traffic advisories on a TCAS II cathode ray tube (CRT)

6/ Photographs taken 'by a camera with two lenses. The spacing between the lenses is equal to the average distance between the human eyes.

display. The subject pilots acquired the intruder visually in 57 of the 66 encounters (86 percent of the total). In five of the nine failures, the failure was partially due to the pilot's response to a TCAS resolution advisory. The median range of the visual acquisitions was 1.4 nmi.

The performance of the pilots was used to provide data for a mathematical model of visual acquisition. This model is based on the experimental observation that the probability of visual acquisition in any instant of time is proportional to the product of the angular size of the visual target and its contrast with its background. The cumulative probability of visual acquisition is obtained by integrating the probabilities for each instant as the target approaches.

The data cited herein were developed by a project leader on the Air Traffic Control Division, Liieoln Laboratories, MIT, who had conducted research on human visual performance and flight testing of collision avoidance systems. At the Safety Board's request, the project leader constructed Probability of Visual Acquisition Graphs based on the extrapolation of pertinent data contained in the facts and circumstances of the collision between the Piper PA-28 and flight 498 with the data described above. (See figures 3 and 4.) The graphs are based on the closure rate between flight 498 and the Piper and on the results achieved by pilots having an unobstructed view of the intruder. The graphs do not account for such limiting factors as cockpit structure and the possibility that the airplanes might be positioned so that they can be seen with only one eye. However, the information in this report is of significance in that it provides a baseline for further evaluation.

1.17 Other Information

1.17.1 Aeromexico Flight Operation Procedures and Training

Aeromexico Air Lines, a foreign air carrier, operates within the United States subject to the provisions of 14 CFR Part 129. Pursuant to the provisions of 14 CPR Part 129.11, Aeromexico must operate within the United States in accordance with Operations Specifications (Ops Specs) issued by the Federal Aviation Administration (FAA). These Ops Specs include the airports to be used, route or airways to be flown, and such "operations, rules, and practices as are necessary to prevent collisions between foreign aircraft and other aircraft." Pursuant to 14 CFR Part 129, Aeromexico fliihtcrews must comply with the provisions of the General Operating and Flight Rules contained in 14 CFR 91 while flying within the United States.

The United States accepts the airman certificates issued by a foreign government as evidence that they have been trained properly and are competent to perform their assigned duties within U.S. boundaries. According to the manager of the FAA Los Angeles Flight Standards District Office (FSDO), the FAA has no reason to believe that it is not justified in continuing this policy. The FSDO manager also testified that the FAA does not "conduct en route inspections aboard foreign carriers outside the United States. We do not routinely conduct en route inspections within the United States unless . . . the foreign carrier requests it for safety reasons."

The Aeromexico Flight Operations Manual contained a specific section addressing collision avoidance. The section contains nine articles which, in addition to commanding their flightcrews to maintain vigilance, amplify and, in essence, reiterate the right-of-way rules contained in 14 CFR Part 91.67.

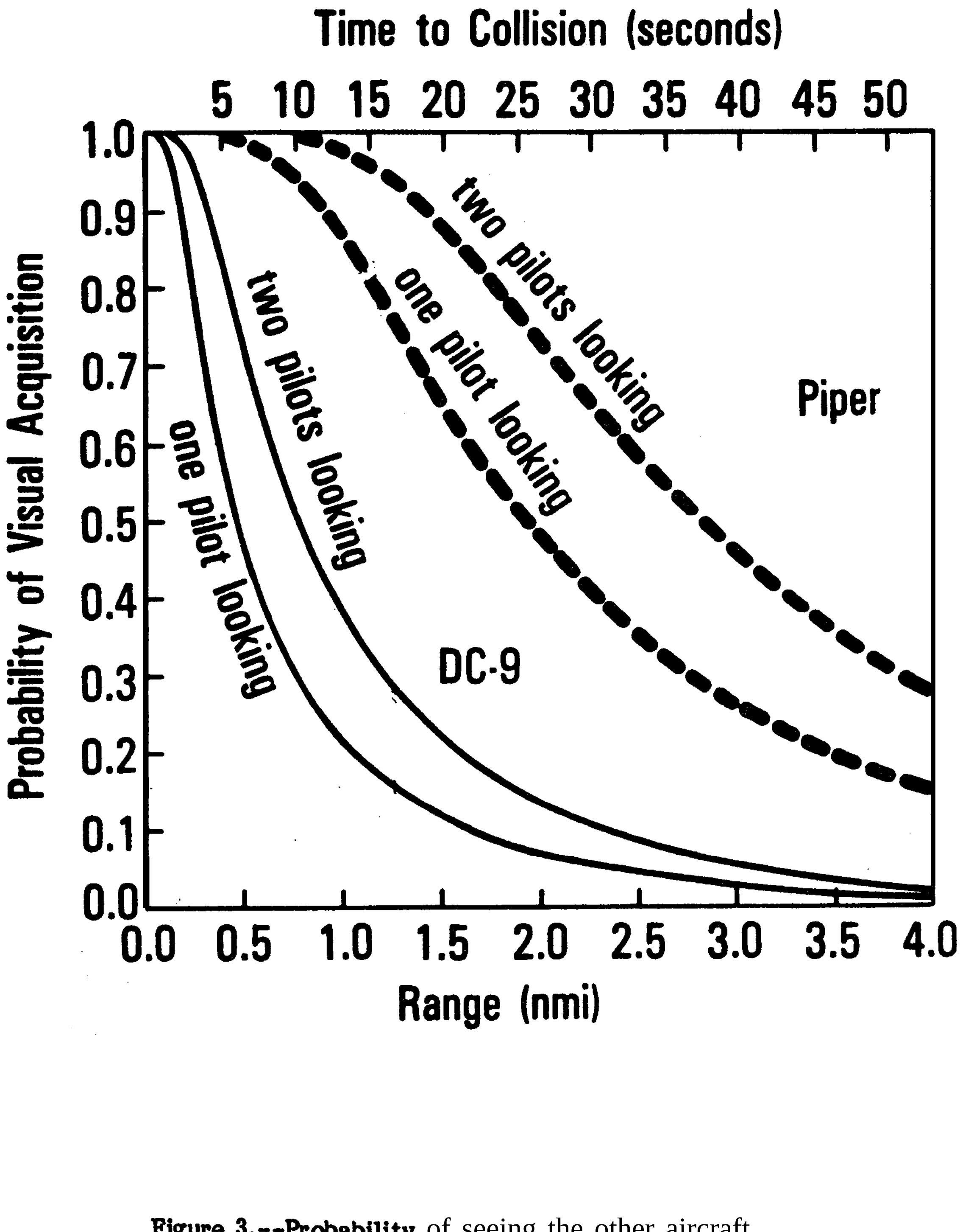


Figure 3.--Probability of seeing the other aircraft as a function of time until collision.

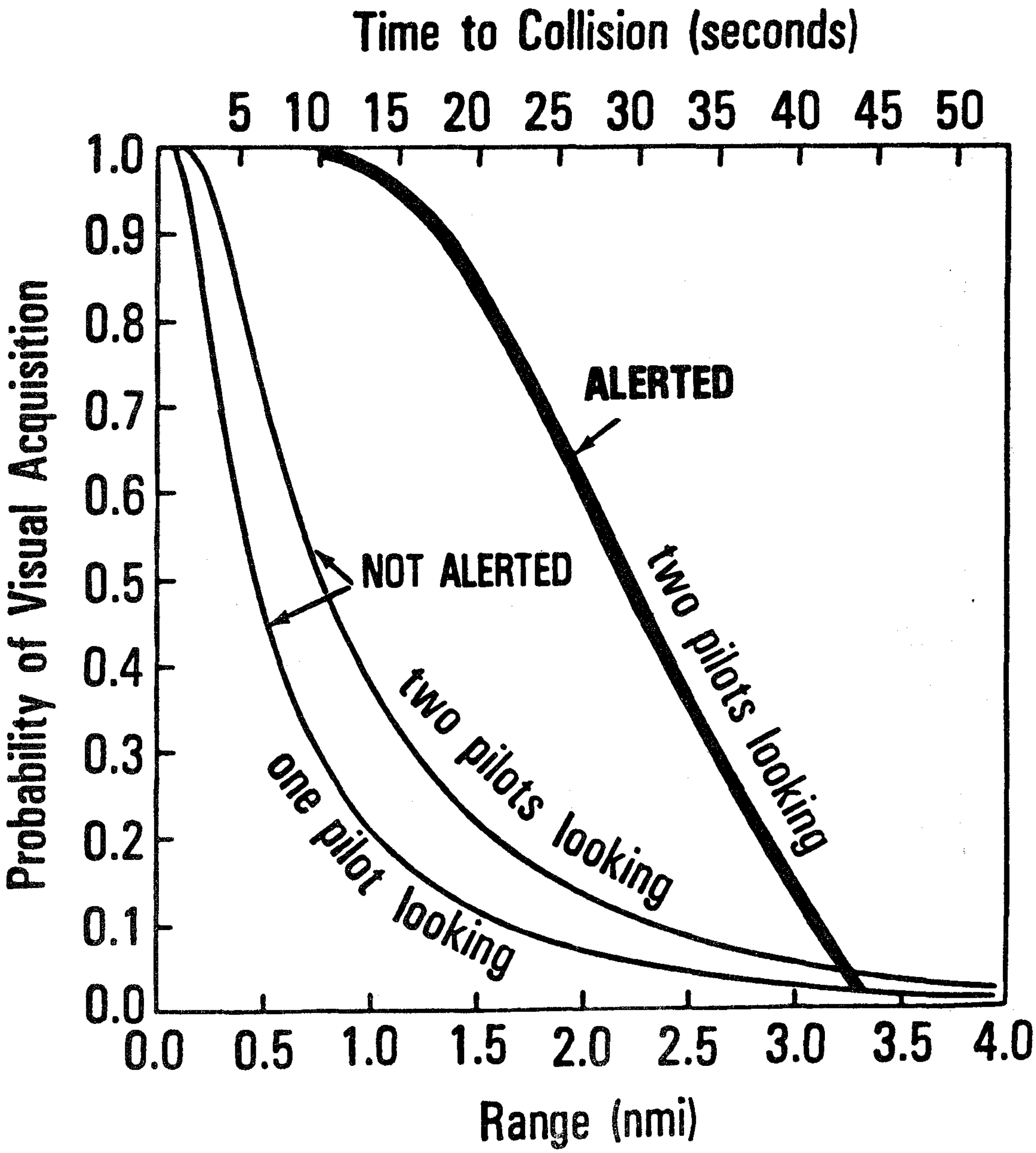


Figure 4.--The effect of TCAS-type alert on the probability that the DC-9 pilot would see the Piper Aircraft.

The Aeromexico recurrent training requirements and curricula were almost identical with those contained in the applicable sections of 14 CFR Part 121, which apply to United States air carriers. Aeromexico DC-9 flightcrew members received recurrent training twice a year. Each recurrent training session included 2 days of ground school during which aircraft systems were reviewed, and either 2 days of simulator or 1 day of flight training on alternate training sessions. Each recurrent training session was followed by an en route flight check, preferably to a destination in the United States.

The Aeromexico Plight Operations Manual stated that the cockpit door will be closed but not looked during flight, and it limited the use of the observer's seat (jump seat) in the cockpit to check pilots and to deadhead company pilots, company technical personnel with proper written authorization, and inspectors from the office of the Director General of Civil Aviation of Mexico (DGAC). The Manual did not contain specific requirements to limit conversation within the cockpit or to prohibit the entry of flight attendants during the takeoff, climb, descent, approach, and landing phases of flight.

Company policy recommended the use of the autopilot for the descent into L.A. International. According to an Aeromexico DC-9 captain and checkpilot, except for takeoff and landing, the autopilot was used throughout all flights. He testified that it was normally turned on about 2,000 feet above the ground (AGL) on departure and remained on until about 300 feet AGL, when it had to be turned off. He testified that he expected that the autopilot would have been engaged when the collision occurred.

The checkpilot testified that he had flown from Tijuana to Los Angeles many times. He testified that company procedures required that all required paperwork be completed while at cruise altitude; however, given the very short length of this flight, no paperwork is done because of the cockpit workload.

According to the checkpilot, Aeromexico had a special abbreviated checklist for use on very short flights or those flown below flight level (FL) 240 7/. He testified that the flightcrew would call for and accomplish the approach checklist about 3 minutes before starting the descent for landing. He testifed that although the prelanding call to the company was generally made 10 to 15 minutes before landing, given the length of this flight and its workload, the call was made after the checklist was completed, but that, "You never start your descent if you're not complying with the descent and approach checklists." He further testified that all checklists should have been completed by the time flight 498 had descended through 7,000 feet.

The check captain was asked about the unintelligible female voice heard on the CVR at 1150:05. He testified that it could have been the flight attendant informing the captain that the cabin was prepared for landing as required by company procedures; it could also have been part of a Public Address System (PA) announcement audible through the cabin door. He said that noises occurring close to the cockpit door are heard in the cockpit, and "You get all the PA announcements through the door. You get all the chimes."

7/ A level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury. Each is stated in three digits that represent hundreds of feet. For example, FL 240 represents a barametric altimeter indication of 24,000 feet.

1.17.2 The Los Angeles Terminal Radar Control

The Los Angeles TRACON was located in a hangar on the south side of the Los Angeles International Airport. The TRACON used two radar systems, an Airport Surveillance Radar (ASR)-4 and an ASR-7 to supply radar data. The ASR-4 radar antenna was located about 1 mile north of the airport and the ASR-7 antenna was located midfield on the south side of the airport. Each antenna operated independently and each had a colocated beacon antenna that interrogated and received aircraft transponder (beacon) signals. The radar system was augmented with an Automated Radar Terminal System III (ARTS III), which included a conflict alert capability, a subprogram that alerts radar controllers to potentially hazardous proximities between aircraft. The aural and visual alerts are based upon projected positional and velocity data for tracked (associated) mode C equipped targets. The Piper was not mode C (altitude reporting transponder) equipped; therefore, the ARTS IIII computer could not be used to provide a conflict alert. The TRACON was equipped with seven vertical and two horizontal Data Entry Display Systerns (DEDS) consoles.

Under normal operating conditions, the ASR-4 supplied data to the AR-l position; the controller assigned to the AR-l position was responsible for the final sequencing of aircraft arriving from the south. The AR-l controller was assigned runways 25L and 25R on the south side of L.A. International and sequenced arrival traffic from the south to these runways. The ASR-7 provided similar data to the AR-2 control position; the AR-2 controller was assigned runways 24L and 24R on the north side of the airport and sequenced arrival traffic from the north to these runways.

With regard to redundancy, either radar system could supply data to both the AR-1 and AR-2 control positions. In addition, each radar system had two independent channels channels A and B --and any one of these four channels could supply data to the controllers' positions. At the time of the accident, the ASR-4 channel B was on line.

The ARTS III system contained three computers, two computers to supply data to the displays and the third as a backup. The ARTS III contains an Air Traffic Control Beacon Interrogator-4 system (ATCBI-4), which received and transmitted beacon information from independent beacon antennas on each radar system antenna. The ATCBI-4 also provided digital beacon code information to the ARTS system to be used by the computer, which provided alphanumeric information to the controllers' displays.

The radar system and the ARTS III normally provided the following portrayal to the controller's display. A primary target, or "skin paint," appeared as a dot of light as the antenna sweep crosses the target's position on the display. This dot of light faded until subsequent sweeps enhanced the target's brightness. If the aircraft was equipped with an active transponder, a beacon control shsh (beacon slash) was disphyed in addition to the primary target and the slash was at a right angle to the origin or apex of the radar sweep on the display.

If ARTS III automation was functioning, as the primary target faded, the computer would maintain the alphanumeric symbol on the display. If a non mode C-equipped airplane's transponder code was 1200, and if the controller had preselected code 1200, a triangle would appear. Thus, a VFR airplane without a mode C altitude encoder would appear as primary target, a beacon slash, and a triangle. If the transponder had mode C, the airplane would appear as a primary target and a square. In addition, its altitude would be displayed as a three-digit figure close to the symbol and associated with it by a leader line. An altitude of 6,000 feet, for example, would be presented as "060".

If the aircraft was a tracked target -- an aircraft whose identity has been inserted into, and therefore was tracked by, the ARTS III computer -- an alphanumeric symbol would appear instead of a triangle or square. Different symbols were used to denote which control position had track control of the targets; targets tracked by the AR-1 position were denoted by the letter "D". All tracked targets have associated with them a data block containing the aircraft identification, ground speed, altitude, and other selected information. Flight 498 would have been displayed as a primary target, with a beacon control slash, a "D", and its data block.

The 10-Channel Decoder - The TRACON also was equipped with an ATCBI-3 beacon system known as a 10-channel decoder. The ARTS III with its internal ATCBI-4 was designed to replace the lo-channel decoder. Other ARTS III-equipped TRACONS use their ARTS III as their primary traffic control system with the lo-channel decoder as a back-up beacon-interrogator system; however, the Los Angeles TRACON used its 10-channel decoder as the primary beacon-interrogator system.

Normally, channels 1 through 8 on the lo-channel decoder are preset and contain 45 discrete beacon codes. Channel 9 was not preset but was normally set on code 1200. Channels 1 through 9 targets were displayed as two beacon control slashes on the controllers' display. Channel 10 was not preset but was normally set on code 4500 series usually assigned to VFR traffic receiving advisory services within the TRACON's airspace; this traffic was portrayed as a triple beacon control slash on the controllers' displays.

The lo-channel decoder has an on/off switch that was normally left in the "on" position at the Los Angeles TRACON. When the beacon/analog switch on the controller's DEDS was placed in the "beacon" position, the 10-channel decoder supplied beacon data to the DEDS. In this configuration, the previously described ARTS III alphanumeric portrayals remained the same; however, except for the 4500 code, which was displayed as a triple slash, beacon slashes were double.

In Los Angeles, two other changes were made to this configuration. Channel 9, which contained the 1200 code, was turned off and the controllers, using the ARTS III preselect function, displayed this code in the systems data area on their DEDS displays. In this configuration, without mode C altitude data, a 1200 code appeared on the displays only as a primary target and an alphanumeric triangle; there was no accompanying beacon slash. A 1200 code with mode C data would have been displayed in a like manner but with an alphanumeric square. The Air Traffic Manager of the Los Angeles TRACON testified that, although there was no written policy, all controllers were required to operate their DEDS displays in the above configuration. He testified that channel 9 was turned off to avoid proliferation of beacon slashes on the controller's displays because of the large number of VFR aircraft in the TRACON's airspace.

ARTS III Capacity - The TRACON's ARTS III can store 180 tracked targets in its central track store, and has a corresponding display buffer capacity for intermediate storage of this information before it is sent to the controller% displays for presentation. It can store 300 untracked targets in its untracked target buffer 8/ for presentation on the DEDS. If the tracked or untracked target data exceed the capacities of their respective buffers, the incoming data cannot be placed in the buffers and therefore will not be displayed on any of their displays. The presence of either one or both of these display

8/ Buffer--A temporary storage area of radar beacon targets that are eligible for display. A tracked target is an aircraft whose identity- has been inserted into the ARTS III computer and, therefore, is being tracked by the computer. An untracked target is a target that has been recognized by and is, or can be, displayed by the computer.

buffer overload conditions will produce a printout on the Automatic Send-Receive (ASR)-37 Console Typewriter at the ARTS III computer's main terminal. Three separate display out (DISOUT) messages can be generated to denote which buffer is overloaded or to indicate that both are overloaded and that data is not reaching the DEDS. However, the printout only appears on the ASR-37 at the computer's main terminal; it is not reproduced at the TRACON displays. No DISOUT printouts were generated at the TRACON on the day of the accident.

There is no priority between the tracked and untracked buffers. Data cannot be removed from the untracked target buffer to accommodate tracked target data that cannot be inserted into an overloaded tracked target buffer. Further, untracked targets being displayed on the displays will not be removed to accept a tracked target from an overloaded tracked target buffer.

The ARTS III computer also generates another type of message to indicate that it is being overloaded. Whenever the number of active tracks data in either buffer reaches 85 percent of its active track capacity, a printout is produced indicating this condition. This condition was not indicated on any printouts on the day of the accident.

In addition, the displays can be saturated with alphanumeric data and they will begin to "flicker" as this condition approaches. In order to maintain the alphanumeric data on the controller% displays at a constant level of illumination, the data must be refreshed 30 times per second. Flicker occurs when the computer connot refresh all the alphanumeric data on the displays within the alloted time. Although data is not lost when this occurs, the alphanumeric data presently displayed will begin to fade and reappear. On the day of the accident, none of the TRACON controllers reported that such a "flicker" had occurred.

Finally, heavy Input/Output (I/O) Processor loading may be manifested by another condition. If the amount of beacon data requested and the keyboard processing increase to the point that the computer starts to fall behind, although no data will be lost, the computer's response to the keyboard entries would become sluggish. None of the controllers on duty at the time of the accident either stated or testified that this condition had occurred.

Maintenance History - The ASR-4 and ASR-7 radars were commissioned in 1964 and 1973, respectively. The ARTS III was commissioned in 1973. In 1978, the radar antennas on both ASRs were upgraded and replaced with ASR-8 radar antennas. According to a radar technician in the FAA Airways Facility section at Los Angeles, the ASR-4 has required more maintenance than the ASR-7; however, he testified that the ASR-4 is a vacuum tube system and the tubes "go bad." Except for the magnetron, or transmitter tube, the ASR-7 is a solid-state radar.

Examination of the maintenance records of the TRACON from January 1, 1986, until the day of the accident did not disclose any instances wherein the TRACON was unable to provide its required ATC services. However, between January and August 1986, it had encountered problems that involved the receipt and processing of altitude information received from the mode C transponders. The computer had been dropping altitude information from the data blocks and, in addition, there was some code changing on assigned radar codes. According to an FAA radar technician in depth (RTID), help was requested from the FAA regional office and headquarters in Washington, D.C. The major source of the problem was traced to local interference and to several elements of the beacon antenna colocated with the ASR-4 antenna that were functioning improperly. The beacon antenna was replaced and, according to the RTID, the problems were resolved by the end of July and the system had been returned to "normal service."

During the week before the accident, there were recurring problems with channel A on the, ASR-4. During that period, channel A was out of service a total of 36 hours 44 minutes. However, radar services were supplied from channel B and if channel B had failed, the TRACON could have switched to the ASR-7 and continued to operate. On August 2, 1986, the ASR-4 channel B failed while. channel A was in the maintenance mode for checking. The TRACON shifted to an all ASR-7 operation for about 33 minutes until channel A of the ASR-4 was available. The TRACON then shifted from the all ASR-7 operation to "normal configuration with ASR -4 Channel A on line."

The present radars at the TRACON are scheduled to be replaced by ASR-9 radars which, except for the magnetron tubes, are solid&ate radars. The ASR-7 will be replaced in mid-1987; the ASR-4 about a year later. The later date for the replacement of the ASR-4 was to accommodate local municipal authorities in resolving a re-siting problem for the replacement radar.

Flight Inspections - On August 31, after the accident, the Seal Beach VORTAC and the TRACON's radar were fliiht checked by an FAA flight inspection airplane and were found to be "operating satisfactorily."

Two additional flight inspections were conducted, one on September 3, 1986, and another on March 11, 1987. These two flight inspections of the TRACON's radars specifically explored the performance of the TRACON's radars in the area and at the altitude of the collision.

A radar beam in the earth's atmosphere is subject to refraction-bending-due to the variation of atmospheric density, which is a function of pressure, temperature, and humidity. The refraction power of the atmosphere increases with increasing pressure and humidity and with decreasing temperature.

The density of the atmosphere normally decreases with height and a radar beam passing through this type of atmosphere is refracted to a curvature of 4/3 the earth's radius. When the vertical refractive index is greater than that which produces the 4/3 curvature, the radar beam is bent somewhat more and the layer of the atmosphere is described as "superrefract ive ". Atmospheric layers that produce greater refraction are described as "trapping" layers. If the radar beam enters a "trapping" layer at a shallow angle, part of the beam becomes trapped because the refraction equals the curvature of the "trapping" layer, which follows the curvature of the earth% surface. This condition can increase the range of the radar at the layer's altitude; however, in extreme cases, the index of refraction is so large that the radar beam returns to earth, limiting the range of the radar and increasing greatly the interference due to ground return.

A layer of atmosphere that refracts the radar beam less than normal 'is described "subrefractive". When a radar beam is refracted in this manner, the radar range at a lower elevation is reduced because the beam doesn't curve as much toward the earth's surface.

Under certain conditions, when a layer of atmosphere just above the radar antenna has a large gradient of refractive index, part of the radar entering the layer at a shallow angle is trapped while that entering at a steeper angle is not. The beam is split, leaving a section of elevation angles with no radar energy; this is called a "radar hole".

The Safety Board obtained low level radiosonde squndings 9/ from the South Coast Air Quality Management District at El Monte,. California, for 1200, August 31, 1986 (the day of the accident), for 1200, September 3, 1986 (the day of the second flight check), for 0600 Pacific standard time (the day a third flight check). These data were used to plot refractive indexes.

The August 31 soundings showed "superrefractive" layers between 1,643 and 1,981 feet, between 4,336 feet 4,661 feet, and between 6,071 feet and 6,754 feet. There was a "trapping" layer between 2,375 feet and 2,955 feet.

The September 3 sounding showed an inversion between 2,056 feet and 4,415 feet. There were “trapping” layers between 2,056 and 2,516 feet and between 4,100 feet and 4,415 feet, and a subrefractive layer between 4,415 feet and 4,995 feet. Given the presence of the two “trapping” layers above the radar antenna, there was probably more refraction than on August 31.

On September 3, 1986, a flight inspection of the TRACON's ASR-4 radar was conducted with a Piper PA-28 N6701H. During this inspection, five counterclockwise orbits were flown around the Seal Reach VORTAC at 5,000, 5,500, 6,000, 6,500, and 7,500 feet. The orbits were flown at a 5 nmi radius from the station. Thereafter, the route of the accident Piper PA-28 was duplicated. The route was first flown in reverse from the collision position to the Torrance Airport by departing the collision position at 6,400 feet at 90 KIAS and descending at 700 feet per minute (fpm). A reciprocal route was then flown by departing the location where radar tracking began at 90 KIAS and climbing at 700 fpm. The second track, which duplicated the course flown by the Piper on the day of the accident, was flown at the same time of day as the accident and was timed so that the flight check airplane would arrive at the impact site at 1152.

During the flight, the ASR-4 radar and the ARTS III were configured as they were at the time of the accident, and the strengths of the primary and secondary targets were scored in accordance with the target strength parameters contained in paragraph 215.5 of the FAA "Flight Inspection Handbook." The parameters contained in paragraph 215.5 for scoring the strength of primary targets are in part as follows:

3 = Usable
Target leaves a trail or persists from scan-to-scan without trail.

2 = Usable
Target shows each scan and remains on the scope for at least 1/2 of the scan.

1 = Unusable
Less than a strength 2 target; a weak target, barely visible; possible miss.

0 = Unusable
No visible target.

With regard to secondary targets, paragraph 215.5 states:

1 = Usable
Target is satisfactory for ATC purposes.

0 = Unusable
Target is unsatisfactory for ATC purposes.

9/ Measurements of wind, temperature, moisture, and height at selected pressure surfaces.

Paragraph 215.5 defines usable target strength as a "target which is not missed/unusable on 3 or more consecutive scans."

The collision site is located on the 350° radial of the Seal Beach VORTAC at 5 nmi from the station. Examination of the scores on the orbits between 5,000 and 6,500 feet and between the 270° and 015° radials revealed the following:

5,000 feet

Between the 355° and the 018° radials, seven out of eight primary target returns are unusable, the rest are u-sable. All secondary targets are usable.

5,500 feet

All primary and secondary targets are usable.

6,000 feet

Three primary targets are unusable at the 328°, 342° and 355° radials. The secondary targets are usable.

6,500 feet

There is one unusable 'primary target at the 353° radial. All secondary targets are usable.

With regard to the two duplications of the accident airplane's flightpath, all secondary targets were usable. On the descending flight toward Torrance, two primary targets were unusable on the first and third sweep or scan of the antenna; the remainder of the primary targets were usable. On the climbing flight from Torrance to the impact site, there were widely separated unusable primary targets, which were only one sweep in duration. However, the primary targets were unusable during the last six sweeps of the antenna before the airplane reached the impact site.

The flightcheck form also contains the outside air temperature recorded during the flight check. At 3,000, 4,000, 5,060, 6,000, and 7,000 feet, the following centigrade temperatures were recorded: 19°, 24°, 22°, 18°, and 16".

The Aii Traffic Manager of the TRACON testified that the area of unusable primary target returns near the Seal Reach VORTAC "was not an area we had previously identified." He testified that the flight check conducted since the accident had pointed out a "couple of areas . . . where there is a problem with the primary coverage and we weren't aware of . . . previously," but that the "beacon (secondary target) coverage was good."

A third flight check of the Los Angeles TRACON's ASR-4 radar was flown on March 11, 1987, as a result of another reported near midair collision (NMAC). On January 31, 1987, Aeromexico Flight 498 was descending towards L. A. International within the confines of the Los Angeles TRACON. While descending through about 6,400 feet, the Aeromexico flightcrew reported sighting a "Cessna" to the TRACON. According to the flightcrew, the Cessna crossed about 2,000 to 3,690 feet in front of and about "300 to 500 feet" above them, but had not been pointed out to them by the approach controller. Upon receipt of the Aeromexico report, the approach controller rechecked his radar display and stated that the Cessna was not depicted on it. He summoned another controller to look for the Cessna's radar return, and the second controller also stated that he did not see any radar target on the display in the area where the Aeromexico flightcrew had reported the sighting.

Flight 498 continued to descend and landed without further incident; the flightcrew did not perform any evasive meaneuver to avoid the Cessna.

Subsequent examination of the March 11 recorded radar data confirmed the Aeromexico flightcrew's report and showed that a code 1200 VFR target had crossed in front of flight 498; however, no altitude information was available for the VPR target return.

The recorded radar data, which included only ARTS III alphanumeric data, indicated that fliiht 498 passed behind the Cessna and that the minumum lateral separation between the two airplanes ranged from about 3/4 mile to 1 3/8 miles as compared to the 2,000 feet to 3,000 feet estimated by the flightcrew. Given flight 498's altitude-6,400 feet-and the flightcrew's estimate of the Cessna's relative altitude, the Cessna was probably above the TCA and the estimated vertical separation probably ranged from 600 to 1,000 feet at the point where the airplanes' tracks crossed. Based on these separation distances, the reported NMAC would have fallen within the FAA's "no hazard" category. The FAA has established the following categories for NMACs:

1. Critical: a situation where collision avoidance was due to chance rather than an act on the part of the pilot. Less than 500 feet of aircraft separation would be considered critical.

2. Potential: an incident which would probably have resulted in a collision if no action had been taken by either pilot. Closest proximity of less than 500 feet would usually he required in this case.

3. No Hazard: a situation when direction and altitude would have made a midair collision improbable regardless of erasive action taken.

Given the fact that flight 498 was near the point where the August 31 collision occurred, the Safety Board requested the FAA to conduct another flightcheck of the TRACON's radars, which they did on March 11, 1987.

The flightcheck was conducted between 1130 and 1230 in the area just east of the Seal Beach VORTAC. The flightcheck airplane, a Cessna 172, was flown between the 15 nmi and 20 nmi DME arc of the Los Angeles VORTAC and the following runs were made:

1. At 5,000 feet; heading 090°
2. At 5,500 feet; heading 270°
3. At 6,000 feet; heading 090°
4. At 6,500 feet; heading 270°
5. At 7,000 feet; heading 090°

The performance of the ASR-4 and ASR-7 radars was checked. However, although the five runs on the ASR-7 were flown at the same altitudes as those flown to check the ASR-4, they were flown on reciprocal headings. The ASR-4 radar, ARTS III, and DEDS were configured as they were at the time of the accident on August 31, 1986, and Safety Board personnel observed the scoring of both radars' performance.

With regard to the ASR-4, except for one miss (at 14 nmi from the Los Angeles VORTAC at 7,000 feet), all primary targets were usable, either 2s or 3s, with the majority being 3s. There was only one unusable secondary target.

The ASR-7 did not perform as well as the ASR-4 and in two instances; the combination 1 and 0 scores required the target to be classified as unusable. Both of these instances occurred on the outbound run (090°) at 6,500 feet at about 18.5 nmi and 20 nmi from the Los Angeles VORTAC; however, all secondary targets were usable. The ASR-7 radar is normally used to monitor and control traffic arriving from the north.

The March 11 sounding showed an inversion between 2,532 feet and 3,920 feet and the atmosphere was moist from the surface to the base of the inversion. There were super-refractive layers between 2,148 feet and 2,857 feet; between 7,974 feet and 9,010 feet but over all, there was less refraction than would have occurred on either August 31 or September 3, 1988.

Recorded Radar Data - Radar data recorded at the Los Angeles TRACON during the time of the accident was acquired by the Safety Board. The tapes contain the data that was sent from the ARTS III I/O Processor to the DEDS units in the TRACON. Since the ARTS III cannot record primary target returns or beacon control slashes, the recorded data contain only the alphanumeric symbology transported from the I/O Processor to the DEDS.

The radar data covering the period of time pertaining to the accident were processed by the Engineering Services Division of the Safety Board's Bureau of Technology. The targets of the DC-9 and the Piper recorded by the ASR-4 and -7 radars were read from the tapes, converted from magnetic to true north, translated into a common coordinate system, and plots of the paths of both airplanes were made. Figure 5 shows the beacon targets of both airplanes for about the last 3 minutes of their flights. Based on this plot, at 1151:17, the DC-9 and Piper were about 3 nmi apart; at 1151:36, they were about 2 nmi apart; and at 1151:55, they were 1 nmi apart.

The recorded radar data also indicated that the Piper passed the TCA's lateral boundary about 1149:47 and that the collision occurred about 3 nmi wast of that boundary. The manufacturer's climb performance chart was based on a 76-KIAS climb speed. Between 5,000 feet and 7,000 feet, based on the airplane's estimated gross weight and the existing weather conditions, the Piper could have climbed at a rate of about 300 fpm to 350 fpm. Since the collision occurred about 1152:09 at about 6,560 feet, the Piper probably climbed through 6,000 feet-the base altitude of this segment of the TCA—about the same time it crossed the TCA's lateral boundary,

The AR-1 controller testified that, based on the range setting he had set in his DEDS, 1 inch on his display equalled about 2 nmi.

1.17.3 Air Traffic Control procedures

The rules, regulations, and procedures governing the conduct of both ATC facilities and controllers are contained in numerous FAA publications and orders. Only those documents relevant to the facts and circumstances involved in the collision have been cited herein.

Paragraph 373b of FAA Order 7210.3G, "Facility Operation and Administration," requires facilities to issue a directive establishing facility standarda for displaying required transponder replies and the. switch positions required for their presentations on the radar display. The paragraph also states in part that ARTS facilities shall also prescribe procedures for monitoring mode 3/A codes with the ARTS in either

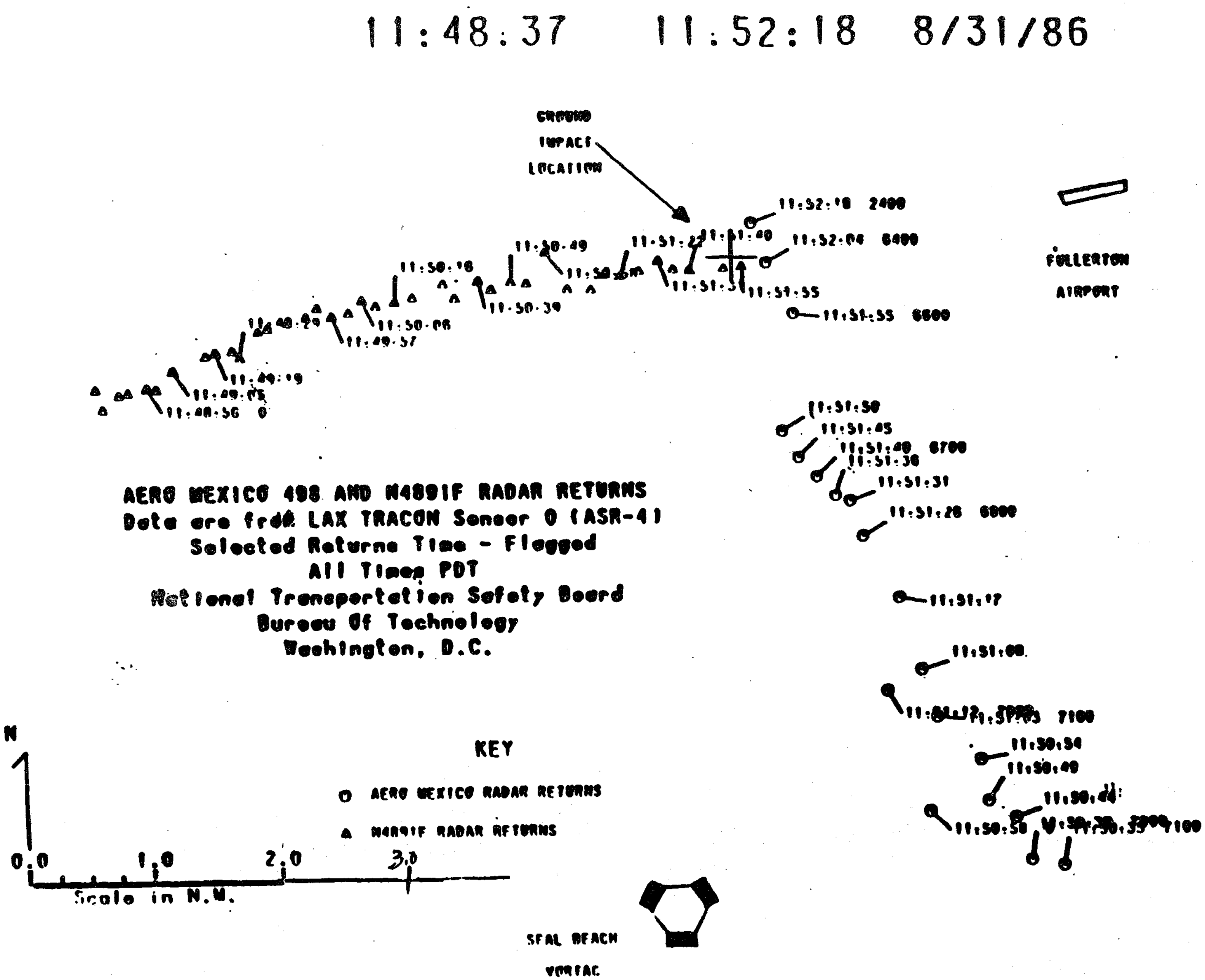


Figure 5.--Beacon targets of DC-9 and Piper during last 3 minutes of flight.

the beacon or analog mode. On March 15, 1984, the TRACON also issued a supplement (7210.3G LAXSUP1), containing the codes to be monitored using the lo-channel decoder. However, the supplement did not iterate the TRACON's standard procedure of using its lo-channel decoder for traffic separation procedures instead of the ATCBI-4 decoder, nor did it state that code 1200 would be inserted into channel 9 of the decoder. Although the directive did not state how the 1200 code was to be monitored, the evidence was conclusive that it was being monitored when the accident occurred.

The AR-l controller% DEDS had been configured in accordance with the provisions contained in LAXSUP 1, and he had inserted the 1200 transponder code into the System Data Area of his DEDS. Therefore, targets on his display were being displayed as described in Section 1.17.2 above. Based on the setting of his altitude filter, all targets between 300 feet and 23,300 feet were being displayed.

FAA Order 7210.65D, "Air Traffic Control" (hereinafter called the Controllers Handbook) contains the procedures to be used by ATC controllers. Paragraph 1.1 of the Controllers Handbook states:

> This order prescribes air traffic control procedures and phraseology for use by personnel providing air traffic control services. Controllers are required to be familiar with the provisions of this handbook that pertain to their operational responsibilities and to exercise their best judgement if they encounter situations that are not covered in it.

Paragraph 2-2 of the Controllers Handbook states in part:

> a. Give first priority to separating aircraft and issuing safety advisories as required in -27- this handbook. Good judgement shall be used in prioritizing all other provisions of this handbook based on the requirements of the situation at hand.
>
> b. Provide additional services to the extent possible, contingent only upon higher priority duties and other factors including limitations of radar, volume of traffic, frequency congestion, and workload.

Paragraph 2-2b contains a note, which states in part:

> The ability to provide additional services is limited by many factors, such as the volume of traffic, frequency congestion, quality of radar, controller workload, higher priority duties, and the pure physical inability to scan and detect those situations that fall in this category.

The AR-l controller testified that the vertical and horizontal separation minimums between IFR and VFR aircraft in a terminal area and within 15 nmi of the antenna are 500 feet and 1 1/2 nmi, respectively. However, paragraph 5-72 of the Handbook states that for aircraft within less than 40 nmi of the radar antenna, the minimum separation is "3 miles."

Paragraph 5-71 of the Controllers Handbook states in part that the controller shall apply radar separation:

> a. Between the centers of primary radar targets; however; do not allow a primary target to touch another primary target or a beacon control slash.
>
> b. Between the ends of beacon control slashes.
>
> c. Between the end of a beacon control slash and the center of a primary target.

The manager of the TRACON testified that while the ARTS III-generated alphanumeric symbology could not be used to separate traffic, he had seen the symbology used as a basis for issuing a traffic advisory.

The Controllers Handbook defines the circumstances that require controllers to advise aircraft of traffic. Paragraph 5-8 contains merging target procedures, which state that controllers shall issue traffic information to those aircraft whose targets appear likely to merge unless the aircraft are separated by more than the appropriate vertical separation minima. The paragraph states in part that this information shall be given to "turbojet aircraft regardless of altitude."

Paragraph 2-21 of the Handbook states in part, "issue traffic advisories to all aircraft (IFR or VFR) on your frequency when in your judgement their proximity may diminish to less than the applicable separation minima." The remainder of the paragraph contains recommended phraseology to describe the relative location of the traffic and its altitude, and it recommended that controllers use the term "altitude unknown" when no altitude data is available.

In addition to traffic advisories, the position of traffic could require the controller to issue a safety alert as prescribed in paragraph 2-6 of the Controllers Handbook. Paragraph 2-6 states in part:

> Issue a safety alert to an aircraft if you are aware the aircraft is at an altitude which, in your judgement, places it in unsafe proximity to . . . 0ther aircraft.
>
> 2-6b. Aircraft Conflict Alert - Immediately issue/initiate an alert to another aircraft if you are aware of another aircraft at an altitude which you believe places them in unsafe proximity. If feasible, offer the pilot an alternate course of a action.

The note (Note 1) appended to paragraph 2-6 states that the issuance of a safety alert

> is a first priority . . . once the eontroller observes and recognizes a situation of unsafe aircraft proximity . . . to other aircraft. Conditions such as workload traffic volume, the quality/limitations of the radar system, and the available lead time to react are factors in determining whether it is reasonable for the controller to observe and recognize such situations. While a controller cannot see immediately the development of every situation where a safety alert must be issued, the controller must remain vigilant for such situations and issue a safety alert when the situation is recognized.

Unless a pilot flying pursuant to VFR is cleared by the **appropriate** controller for fliiht in either a TCA, a Terminal Radar Service Area **(TRSA),** or an Airport Radar Service Area **(ARSA)** that provides conflict resolution, VFR aircraft do not receive air traffic control separation service from controllers. Paragraph 2-2 of the Controllers Handbook states in part, **"give** first priority to separating aircraft. . . **."** Since only IFR aircraft are provided traffic separation services, the controller% first priority is to separate IFR airplanes from IFR airplanes. Except for issuing a safety alert which, pursuant to paragraph 2-2, has the same priority as separating traffic, all other duties fall within the category of additional services and will be provided subject to the conditions contained in paragraph **2-2b** of the Controllers Handbook.

The AR-l controller testified that the center or origin of the radar sweep had been offset **to** the left side of his display and was located about 5 nmi west of **L.A.** International. **The** range markers were 5 nmi apart and extended out to 30 nmi from the center or origin of the sweep. Given this configuration, the area of coverage on his display extended about 40 to 45 nmi east of L.A. International and included a video map showing the horizontal boundaries of the TCA. However, while any radar target that was inside the horizontal boundaries of the TCA would be displayed within its confines on his video map, the controller would not know if the target was within the TCA vertical limits without either a mode C altitude readout or an **altitude** report from a pilot. The controller testified that regardless of where a VFR target was located on his display, workload permitting, he would provide traffic advisories where applicable.

The AR-l controller testified that he had configured his DEDS to display primary targets and that the primary targets, as presented on his display, were "about the size of an eraser, maybe two erasers side by side, a standard size pencil eraser. Not a pinpoint of light." He controlled the brightness of the primary target with the **MTI** (moving target indicator) Normal Video Gain **(MTI/Video** Gain) control knob on the control console of his PVD. He testified that "Generally the **MTI** is adjusted to near its full intensity. You adjust to where you get good clear target presentation without overblooming or out of focus effect."

Examination of the ATC transcript (see appendix I?) showed that the AR-l controller had provided three traffic advisories concerning untracked VFR targets to **airplanes** under his control within the TCA. The advisories were issued at **1142:16, 1146:11,** and **1150:39;** none of these reported targets were mode C-equipped. At **1150:46,** the AR-l controller advised flight 498 of "traffic, ten o'clock, one mile, northbound." As subsequently shown by the recorded radar data, the target in question was a non-mode C target displaying a discrete beacon code indicating that it was being controlled by another facility. With regard to his workload, the controller characterized the traffic as **"light."**

The AR-l controller stated that he would issue a traffic advisory to an airplane whenever the traffic **"in** my opinion, will come to a spot where I will have less than applicable separation." He said that he would issue an advisory about any traffic inside the confines of a T-shape that he **projected** mentally ahead of the airplane he was controlling. The vertical bar of the **"T"** was projected 3 nmi ahead of the airplane and along its line of **flight;** the crossbar of the **"T"** extended 3 nmi either side of the vertical bar. The controller stated that after flight ,498 **passed** the traffic he had pointed out at **1150:46,** he did not see any traffic **that** he considered a factor to the continued progress of flight 498. The AR-l controller stated that the Piper **"was** not displayed. It is my belief that he was not on my radar scope.**"** He **testified** that if he had seen the Piper, he would have issued a traffic advisory to fliiht 498.

At 1151:57, after instructing flight 498 to maintain its present airspeed; the AR-I controller asked the flight to stand by for "a change in plans." According to the controller, he had been informed by the traffic coordinator that flight 498 could use runway 24 right for landing.

At 1151:23, the AR-l controller answered the initial radio call from the Grumman Tiger, N1566R. At 1151:26, N1566R informed the controller that it was a VFR flight from Fullerton to Van Nuys, that its altitude would be 4,500 feet, and that it was requesting flight following services. The AR-l controller testified that he did not respond immediately because at that time the arrival coordinator "was informing me that Aeromexico 498 could have runway 24." The controller testified that after receiving the coordinator% message, he began to check the traffic inbound to the airport from the east to see if he would have any problems inserting flight 498 into the landing sequence for runway 24R. At 1151:45, he instructed flight 498 to "maintain your present speed." He testified that, between 1151:45 and 1152:00:

> when the conversation was going on with Aeromexico, and I was attempting to get him to maintain his present speed...At that point in time I looked over to the AR-2 scope (the AR-2 display is located next to his display) to see what possible traffic they might have for Aeromexico to see if the speed difference was going to make any difference in his sequence into Los Angeles.

With regard to the appearance of N1566R on his frequency at 1151:18, the controller testified that although he did not respond immediately after receiving N1566R's request for flight following, he was aware of his route of flight and requested altitude en route to Van Nuys. The controller testified:

> At this point in time his response indicated to me that if he were not in the TCA already, he would probably be on a course of flight that would place him there very shortly and at an altitude that would place him in the middle of the TCA. (Except for two very short segments, the floor of the TCA along N1566R's stated route of flight was essentially either 2,000 feet or 2,500 feet.) I can recall scanning along the line of flight from Fullerton up towards Van Nuys to see if I had any targets indicating 4,500 feet that might possibly be six six Romeo.

The controller testified that since N1566R's message did not mention the TCA, since the requested altitude was above the floor of the TCA, and since the pilot did not say that he, would remain clear of the TCA, "it was just my professional opinion at that time that he would be in my airspace." The recorded ARTS III keyboard entries also showed that, at 1151:37, the AR-l controller inserted the N1566R indentification into the ARTS III to obtain a discrete VFR code to assign to the airplane.

At 1152:04, the AR-l controller told the N1566R pilot to set 4524 in his transponder. At 1152:14, N1566R's beacon return was acquired automatically by the ARTS III; however, the controller did not contact N1566R until 1152:29. At that time, N1566R was about 15 nmi east of L.A. International, climbing through 3,400 feet, and inside the TCA. (See figure 1.) The AR-l controller testified that when he saw N1566R's radar target, it "became my primary duty to resolve what was a potential conflict developing between six six Romeo and Wings West 5083." He testified that about 1152:36 he noticed that the computer was no longer tracking flight 498. He made two further transmissions that were unacknowledged to the flight and then saw:

1 had lost (flight 498's) primary target; At that point I notified the arrival coordinator that I had lost radio contact with Aeromexico 498 and shortly thereafter notified him that I had also lost radar contact with Aeromexico 498."

L17.4 Terminal Control Areas

The FAA introduced TCAs and other air traffic control measures aimed at reducing midair collision potential during the early 1970s after a series of midair collisions involving 12 air carrier aircraft. Since 1972, two midair collisions involving air carrier aircraft have occurred in terminal areas: the collision over Cerritos and a collision over San Diego on September 25, 1978, between a Pacific Southwest Airlines Boeing 727 and a Cessna 172 (NTSB-AAR-79-S). No TCA existed at San Diego when the Pacific Southwest Airlines collision occurred; consequently, the Cerritos midair collision was the first to occur within a TCA.

Presently, 23 TCAs are in existence: 9 Group I TCAs and 14 group II TCAs. (Group I and II classifications are based on the volume of traffic and the number 'of passengers enplaned annually at the TCA's primary Airport.) Each TCA includes one primary airport and these 23 airports are among the busiest of all terminals in aircraft operations and passengers carried. During 1984, TCA hub airports handled about 18 pecent of all aircraft operations reported at FAA control towers and about 64 percent of the enplaned passengers in the United States.

A TCA is a region of airspace surrounding large air transportation hubs within which a combination of regulatory airspace operating rules and air traffic procedures are used to reduce the midair collision potential. These high density terminal areas contain complex air traffic conditions due to the mix of aircraft present and their wide range of performance characteristics. Under these traffic' conditions, separation between aircraft cannot be ensured if unauthorized transient aircraft proceed through the area at altitudes used by arriving and departing aircraft. Thus, appropriate regulations require authorization from ATC prior to the operation of an aircraft within the TCA. In addition to requiring ATC authorization before entering these TCAs, 14 CFR Part 91.90 levies additional procedural and airplane equipment requirements as a prerequisite for operating within group I and group II TCAs. The group I requirements are as follows:

1. A VHF Omni-directional range (VOR) or Tactical Air Navigation (TACAN) receiver (except helicopters)

2. A two-way radio capable of communicating with ATC

3. A 4096 code transponder with mode C altitude reporting equipment

4. A private pilot certificate to land or take off from an airport within the TCA

5. Unless otherwise authorized by ATC, each person operating a large turbine powered airplane to or from the primary airport shall operate at or above the designated floors while within the lateral or vertical confines of the TCA.

Except for the following two provisions, the requirements for operation within a group II TCA are identical to those above:

1. A mode C altitude reporting capability is not required; however, beginning December 1987 it will be required.

2. Student pilots are permitted to take off and land from airports within the TCA.

After the Cerritos collision, the FAA examined the NMACs received from pilots during 1984 and 1985. During this period, 295 NMACs (22 percent of the total filed) occurred in or near TCAs. Of these, 95 occurred inside a TCA; 26 occurred in airspace underneath a TCA; 14 occurred above a TCA but below 12,500 feet; 53 occurred outside TCA airspace but within 30 nmi of the TCA's primary airport; and 107 occurred in Airport Traffic Areas or at non-towered airports underneath or just outside TCA airspace.

Since these data indicated problems within or near TCAs, the Administrator of the FAA convened a TCA Review Task Group on September 16, 1986, to study the effectiveness of the TCA program. The work of the group was divided into three principal areas:

A. TCA Airspace Enforcement Issues

B. TCA Concept and Design Issues

C. TCA Educational Issues.

The Task group completed its work on October 15, 1986, and according to one of its task group commanders, submitted about 40 recommendations to the Administrator. On October 30, 1986, after reviewing the group's recommendations, the Administrator accepted 39 recommendations and ordered that the FAA act to implement them (appendix G).

The adopted recommendations included proposals designed to simplify and standardize the lateral and vertical boundaries of the TCAs; proposals designed to enhance enforcement procedures and to increase the penalties imposed upon pilots who intrude into TCA airspace; and a proposal to require aircraft flying within 30 nmi of the TCA airport to be mode C-equipped and to use the mode C equipment.

On June 11, 1987, the FAA issued a Notice of Proposed Rule Making (NPRM), Terminal Control Area (TCA) Classification and TCA Pilot and Equipment Requirements, which described rulemaking which would implement those action items for TCA simplification and enhanced mode C requirements. A single class TCA design would be established and is described generically to include an area encompassed by three concentric circles, the innermost with a radius of 10 nmi from surface to 12,500 feet; the second with a radius of 10 to 20 nmi from an altitude of approximately 3,000 feet to 12,500 feet; and the third with a radius of 20 to 30 nmi from an altitude of 5,000 or 6,000 feet to 12,500 feet. The mode C transponder would be required for all aircraft operating from the surface upward with 30 nmi of the major airports within the TCA. The rulemaking would apply to all 23 sites presently having a TCA. Additionally, the NPRM preamble indicates that nine more airports would meet the criteria for a TCA.

With regard to the enforcement of the regulations that protect the airspace of the TCAs, the task group found that most TCA incursions were not being reported by Air Traffic or others as violations. In some cases, the controller in contact with, the pilot simply tells him he is in violation and issues a corrective instruction. However, in many cases, the intruding aircraft is not noticed or is not recognized as being in the TCA because:

1. The controller in a high traffic environment may be too busy to monitor traffic he is not working or to report the violations he does observe.

2. Many violations are either primary targets or VFR beacon targets without altitude readouts and the controller generally cannot determine that the airplane is operating within the vertical confines of the TCA.

3. Many, if not most, violations observed by the ATC controllers are not referred to FAA flight standards offices for enforcement because the aircraft and/or its pilot cannot be identified.

Additional, as well as corroborative, evidence of problems in this area was elicited by the Safety Hoard during its investigation and during the public hearing. The AR-l controller testified that, with regard to TCA intrusions, the number varied and "it could be anywhere from zero to 10 or 15 a shift that I will observe."

The Air Traffic Manager of the Los Angeles TRACON stated during an interview that between April 1985 and the time of the accident, the facility had noted 23 TCA incursions. At the public hearing, the Air Traffic Manager testified that between the time of the accident and December 2, 1986, the facility had filed 32 incident reports "and the majority of those were TCA violators. . . ." He further testified that this increase did not occur "automatically." After the accident, the facility had increased the "emphasis on tracking them (TCA intruders)."

Pursuant to FAA procedures, the TRACON forwarded these cases to the Los Angeles Flight Standards District Office (FSDO) for further processing and enforcement action. The manager of the Los Angeles FSDO testified that, as of December 2, 1986, the FSDO had processed "almost 200 enforcement actions" of all types. With regards to TCA violations received from the Los Angeles TRACON, between January 1, 1986, and December 2, 1986, the FSDO had received about 38 to 40 violations for processing; 32 of these had occurred after the accident.

The FSDO manager testified that processing of enforcement investigation "has second priority behind accident investigation" in his office. He testified that "next to some problems regarding chain of evidence, I would say that pilot identification is the foremost problem in the prosecution of a pilot deviation, TCA, or otherwise." He added,

> Chain of evidence usually refers to handoffs where the aircraft is being tracked from one sector to another, (or) maybe from one facility to another, and we have to provide a chain of evidence to (prove) . . . that we're talking about the same airplane.

With regard to the FSDO workload, he testified that in order to process cases at the rate of 10 to 11 per month, the rate that existed since the accident, it would be necessary to curtail some of the other FSDO workloads.

1.17.5 Traffic Alert and Collision Avoidance Systems

Between 1955 and 1965; most research to develop airborne collision avoidance systems was conducted by aviation or aviation-related corporations such as McDonnell Douglas, Minneapolis Honeywell, and Radio Corporation of America (RCA). Each of these corporations produced collision avoidance systems; however, these systems did not work unless both airplanes had identical equipment of the same technology. About 1974, the FAA began a parallel investigation of the possibility of using the existing air traffic control transponder as an element in an airborne collision avoidance system. Research and investigation based on the development of a system using the transponder continued and resulted in the development of the Traffic Alert and Collision Systems (TCAS) I, IL and IIL The three systems are designed to provide reliable aircraft separation, based on time, not distance, from other transponder-equipped aircraft. TCAS has three levels of sophistication. The simplest and least costly level, TCAS I, will alert the pilot by using visual and, or aural alerts when other aircraft are close; however, it will not provide resolution advisories to the pilot. General aviation pilots are expected to be the principal users of the TCAS L

TCAS II is designed to provide reliable aircraft separation from other transponder equipped aircraft in traffic densities as high as 0.3 aircraft per square nautical mile (24 transponder-quipped aircraft within 5 nmi of the TCAS II-equipped aircraft). The TCAS II equipment in the aircraft interrogates transponders and altitude encoders on aircraft in its vicinity and listens for transponder replies. By computer analysis of these replies, the TCAS II equipment determines which aircraft represent potential collision threats and provides appropriate aural and visual display indications (or advisories) to the flightcrew to ensure separation.

When the TCAS II computer determines that an aircraft is a threat, it generates a symbol representing the intruder on either the aircraft's weather radar display or a cathode ray tube designed to present this information. The computer then provides range and bearing information about the intruder. This information is generally displayed when the aircraft are about 40 seconds apart. If the intruder is mode-C equipped, its relative altitude to the receiving airplane is also displayed next to its symbol. If the threat persists, the pilot receives a resolution advisory 15 seconds later (about 25 to 30 seconds before the predicted time of closest approach). A red light illuminates and the vertical resolution advisory-the best climb or descent maneuver the pilot could take to avoid this intruder--is given to the pilots orally and pictorially on his vertical velocity indicator. The oral advisory can also be in the form of preventative commands, i.e., don't climb; don't descend.

If the intruder is not mode C-equipped, question marks are displayed in place, of the relative altitude next to the intruder symbol, and range and bearing information are displayed. If the threat persists, the TCAS II system does not provide a resolution advisory. About 25 to 30 seconds before predicted time of closest approach, the red light illuminates and the range and bearing of the intruder continues to be displayed, thus indicating to the flightcrew where they are to search visually to locate the intruder.

The TCAS III, the most sophisticated of the TCAS family, is almost identical to TCAS II except that TCAS III provides flightcrews with both horizontal and vertical resolution advisories. Because the TCAS III provides horizontal resolution advisories, it is equipped with an improved beacon antenna that provides more accurate bearing information to the TCAS computer. The improved beacon bearing information also reduces the number of unnecessary alerts. However, with regard to the efficacy of the vertical escape maneuver, the Manager of the FAA's Aircraft Engineering Division of the

Office of Airworthiness testified that they had never seen an encounter that could not be handled with the vertical maneuver. "I do agree that the horizontal maneuver adds a third dimension which in some cases might be more desirable, but as far as it will handle it, the vertical maneuver will do the job."

The Manager of the FAA's Airborne Collision Avoidance and Data Systems Branch testified that the FAA had recreated the Cerritos collision geometry to test the performance of the TCAS III system. He testified that since the intruder was not mode C-equipped, it made no difference which system was used since neither system could supply a resolution advisory. During the test, the TCAS provided a solid traffic advisory "from a point between thirty and forty seconds to the time of closest approach." The manager compared the traffic advisory provided from the TCAS to that provided by an ATC controller. He testified

> it (the TCAS alert) would be like the best traffic alert you ever got in your life, plus, it stays on the whole time. It's...almost another magnitude better in the information it conveys to you than air traffic control can normally do.

Although the FAA has been flight testing TCAS III since 1983, it has not been certified and further testing is still needed. However, three U. S. Air Carriers have either begun, or will begin, to fly the TCAS II in Limited Installation Programs (LIP). On March 18, 1987, Piedmont Air Lines began evaluation flights with a Sperry Dalmo Victor TCAS II installed on one of its Hoeing 727s. As of July 6, 1987, the system had accumulated 280 hours. It has provided 220 cautions and 21 warnings. With regard to responding to resolution advisories during this program, the FAA requires the Piedmont pilots to acquire the intruder visually before performing the advisory's requested maneuver. The Piedmont LIP is scheduled to begin in early September.

United Air Lines is scheduled to begin its LIP in November 1987, with Bendix TCAS IIs installed on two airplanes: a McDonnell Douglas DC-8 and a Boeing 737. Northwest Air Lines is scheduled to begin its LIP in October 1987 with a Sperry Dalmo Victor TCAS IIs installed in two McDonnell Douglas MD-80 airplanes.

On May 8, 1987, the FAA stated that they intended to initiate an NPRM which, if adopted, will require that air carrier aircraft be equipped with a TCAS.

1.18 New Investigative Techniques

1.18.1 Retrack Program

The Retrack Program Computer at the FAA Technical Center, Atlantic City, New Jersey, can demonstrate almost every aspect of the ARTS III computer program. The retrack program can, through the use of recorded data, recreate the ARTS III alphanumeric symbology shown on a controller's display for the data recorded. However, the retrack program cannot display either raw radar returns (primary targets, ground clutter) or analog beacon control slashes since this information is not recorded. Thus, the retrack program cannot replicate the entire radar portrayal on a controller's display; it only replicates the alphanumerics generated by the ARTS III program and its associated logic aspects.

On March 4, 1987, the data recorded by'the Los Angeles TRACON's ARTS III I/O Processor for the time immediately before and-including the accident were inserted into the FAA's Retrack Program Computer. The Retrack Computer had been programmed with the Los Angeles TRACON's ARTS III program; control settings on the test DEDS replicated the control settings used by the AR-l controller on the day of the accident. The inserted data produced the alphanumeric symbols generated by the ARTS III for both flight 498 and the Piper PA-28, and their tracks were similar to those contained on figures 3 and 4. In addition to these two airplanes, the alphanumeric symbols of other airplanes generated by the ARTS III radar were shown, however, the reproduced display did not show primary targets, beacon slashes, video maps, or any ground clutter that might have been displayed on the AR-l controller's PVD at the time of the accident.

The plot of the alphanumeric target symbols contained on figure 4 showed that the target symbols of both accident airplanes were being displaced back and forth in azimuth ("stitching") as they proceeded toward the collision point. The amount of the lateral displacement, when measured angularly at the beacon radar antenna, was about 2° to 3°. This "stitching" movement was visible on the display produced by the Retrack Program. The ARTS III specialists at the Technical Center stated that the "stitching" was caused by distortion of beacon code replies from the interrogated transponder. The distortion could be produced by overlapping beacon replies from two or more airplanes or by deficient suppression of the side lobes of the beacon interrogation signal from the beacon antenna at the radar site. The improper side lobe suppression 10/ could be the result of a hardware problem or misadjustment. A deficient side lobe suppression allows the beacon interrogation and response to continue for a longer portion of the beacon antenna sweep. Thus, the received beacon signal will subtend a longer than normal arc at the target range on the controller's display. The ARTS III computer places the alphanumeric target symbol at the computed centroid of the received beacon train. If a portion of the beacon's response is garbled by inteference with other airplanes' beacon signals, the portion of the beacon which is not garbled will appear as a good and full beacon train and the centroid will be offset.

ANALYSIS

2.1 GENERAL

Roth airplanes were maintained in accordance with all applicable regulations and, with regard to the DC-9, company procedures. There was no evidence that any airplane malfunction contributed to the collision.

The captain and first officer of flight 498 were certificated properly, trained, and qualified to perform their assigned duties. There was no evidence of any preexisting physiological or psychological disability that would have decreased their abilities to perform their inflight duties.

10/ The beacon antenna is colocated and rotates with the ASR radar antenna and transmits an interrogation signal to which airborne transponders reply. The antenna is designed so that the main lobe of the interrogation signal is concentrated in the direction the antenna is pointing and limited in width so that it subtends a small arc during any point of the antenna's rotation. The interrogation signal also contains side lobes of smaller amplitude than the main lobe. To prevent the airborne transponder from replying to the side lobes of the signal, the beacon antenna also transmits a control signal. The relative amplitude of the interrogation signal and control signal is adjusted so that only in the desired arc of interrogation (main lobe of the interrogation signal) is the amplitude of the interrogation signal greater than the amplitude of the control signal. The airborne transponders will reply only when the interrogation signal is dominant.

The pilot of the Piper PA-28 was properly certificated and qualified to conduct the intended flight to Big Bear. There was no evidence of any preexisting psychological disability that would have &creased his ability to conduct the intended flight; further discussion of preexisting physiological conditions that could have affected the conduct of the flight is contained in a later section of this analysis.

The AR-l controller was certified, trained, and qualified to provide the required ATC service. There was no evidence of any preexisting physiological or psychological disabilities that would have decreased his ability to perform his required duties.

The evidence was conclusive that the collision occurred within the Los Angeles TCA; that the Piper pilot had entered the TCA without having been cleared to do so; that the AR-l controller did not advise flight 498 of the position of the Piper; and that neither pilot tried to perform any type of evasive maneuver before the collision. Given these data, the major thrust of the Safety Board's analysis was to identify those factors that led to the events cited above and the resultant collision.

2.2 The Accident

Collision Geometry-The collision occurred as flight 498 was descending through about 6,660 feet. The radar data showed that the DC-9 was on a northwesterly track and the Piper on an eastbound track that traversed the DC-9 track from left to right.

The collision damage on the DC-9 was confined to its vertical and horizontal stabilizer. Although much of the structure of the DC-9 forward of the empennage was consumed by fire, there was no evidence of midair collision damage on those pieces of structure that were not consumed by the fire.

The damaged areas on the DC-9 vertical and horizontal stabilizers contained propeller slice marks, paint transfer marks Rom the nose wheel area and vertical stabilizer of the Piper, and embedded pieces from the cabin roof area of the Piper. The location and angles of these marks and damage on the DC-9, when matched to their respective locations on an intact Piper PA-28, showed that the front of the Piper had struck the left side of the DC-9 vertical stabilizer and that the impact angle was perpendicular to the longitudinal axis of each airplane. (See figure 6.) The impact angle was generally consistent with the flight tracks of the airplanes shown on the radar data plots.

The absence of any impact marks or damage on those portions of the DC-9 left wing and fuselage forward of the empennage that had not been consumed by fire and the damage to the DC-9 vertical and horizontal stabilizers, showed that the PA-28 airplane was about 8 to 10 feet above the top of the DC-9's fuselage and about 15 to 17 feet above its wings when the collision occurred. The damage also indicated that the longitudinal axis of the Piper was almost level at impact and that the initial impact was -with the DC-9 vertical and horizontal stabilizers. The debris from the Piper cabin roof, embedded in the leading edge of the DC-9 horizontal stabilizer, and the fact that the roof of the Piper was sheared off at about the same height on both sides of its fuselage, confirmed the fact that the DC-9's horizontal stabilizer struck the top of the Piper's fuselage and that the Piper was in the almost wings-level attitude at impact. (See figure 7.)

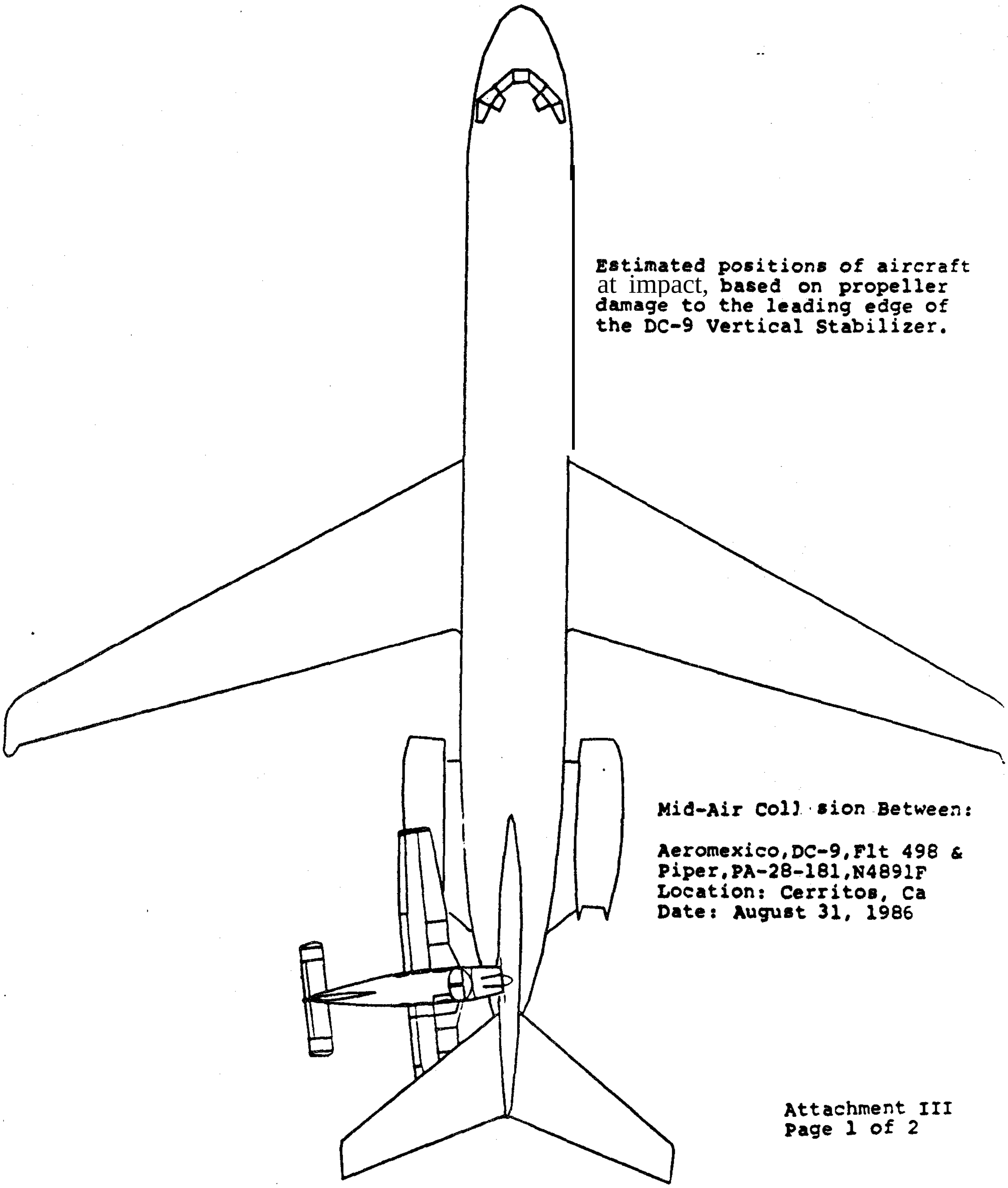
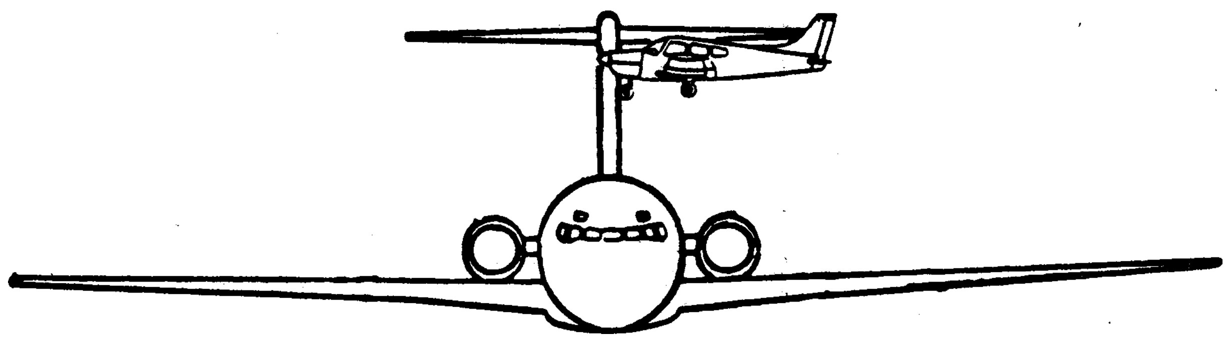


Figure 6.--Collision geometry as viewed from above the DC-9.

Estimated positions of aircraft at impact, based on the propeller damage and scratch marks on the DC-9 Vertical and Horizontal Stabilizers.



Mid-Air Collision Between:

Aeromexico, DC-9, Flt 498 &
Piper, PA-28-181, N4891F
Location: Cerritos, Ca
Date: August 31, 1986

Attachment III
Page 2 of 2

Figure 7.--Collision geometry as viewed from in front of the DC-9.

Even though the Piper was a much smaller and lighter airplane, its engine, a relatively massive object, struck the DC-9 horizontal stabilizer's main support structure, causing it to fail and the horizontal stabilizer to separate. Longitudinal control and stability was lost when the horizontal stabilizer separated and further controlled flight was impossible.

Survival Factors -- Flight 498 fell to the ground from about 6,560 feet and the oecupiable area of the airplane's cockpit and passenger cabin was destroyed by massive impact forces and postcrash fire. Although the occupants of the DC-9 survived the midair impact, this was an unsurvivable accident for the passengers and crew because of the massive ground impact forces.

The DC-9's horizontal stabilizer sheared off the top of the Piper's cabin and its leading edge contained embedded pieces of human remains and hair along with pieces of the Piper's cabin roof. The evidence showed that the three occupants of the Piper were injured during the initial impact and that the injuries were not survivable.

The crash, fire, and rescue units involved in the response performed in a timely and efficient manner. The accident occurred at 1152; the alarm was received at 1153; units were dispatehed at 1154; and the first vehicles arrived at the scene at 1158. In addition to the units described above, local law enforcement units were on the scene within 6 minutes after the accident. The crash scene fire was contained within 30 minutes after the first fire engines arrived and was extinguished 35 minutes later.

2.3 Entry into the Terminal Control Area

Since the Piper pilot entered the Los Angeles TCA without an ATC clearance, the Safety Board sought to determine if the entry had been deliberate or inadvertent.

The occurrence of a myocardial infarction (heart attack) is disclosed during an autopsy examination by areas of dead or dying coronary tissue caused by the obstruction of the blood vessels. Although the data contained in the Piper pilot's autopsy protocol did not contain any evidence of this type of tissue damage and thus showed that he had never suffered a heart attack, medical authorities agreed that it was beyond current medical technology to determine from autopsy evidence whether the pilot could have experienced a myocardial infarction during the time immediately preceding the collision. For the area of necrotic tissue produced by a myocardial infarction to appear in an autopsy, the infarction would have had to occur at least 12 hours before death. Given these facts, and the existing moderate to severe arteriosclerosis found within the blood vessels of the Piper pilot's heart, the Safety Board sought to determine if the pilot had suffered a disabling heart attack and, thereafter, entered the TCA inadvetently.

The Piper pilot had no history of heart problems and had passed his Electro cardiograph (ECG) tests on every previous physical examination (including a resting ECG 8 months before the accident). Even in the highest statistical risk categories for his age, the predicted probability that the Piper pilot would experience a fatal heart attack was less than 5 percent annually 9/.

9/ Schatzkin, A.; Heeren, T.; Morelock, L.; Muscatel, M.S.; and Kannel, W.B. (1984). 'The Epidemiology of Sudden Unexpected Death: Risk Factors for Men and Women in the Framingham Heart Study. American Heart Journal 107, 1300-1306.

The recorded radar data showed that the Piper PA-28 pilot proceeded almost directly to the collision point after he took off from Torrance. Based on the time the Piper PA-28 left Torrance--about 1141-- the airplane's rate of climb from takeoff to impact averaged about 550 fpm. Based on the three flight simulations, this average climb rate was within the airplane's performance capability. In addition, the recorded radar data of the Piper's progress does not contain any type of dramatic disturbance of either heading or groundspeed that might be expected if the pilot had experienced a disabling heart attack. Except for a couple of small turns, the fact that the airplane maintained an almost constant heading and groundspeed indicated that its progress was being monitored and managed.

In addition, if a disabling heart attack allowed the Piper PA-28 to enter the TCA and climb to the 6,560-foot collision altitude, given the average 550 fpm rate of climb, the pilot had to be disabled at least 2 to 2 1/2 minutes before the accident. Based on his proposed route of flight and assuming that the pilot was still alert, the last available proper VFR altitude for fliiht below the floor of the TCA was 5,500 feet. The Piper would have reached 5,500 feet 1 minute before entering the TCA and 2 minutes before reaching the collision altitude. Since the pilot did not level off, the Safety Board, if it is to accept the hypothesis of a heart attack, must conclude that the pilot was incapacitated before the Piper reached 5,500 feet and that the airplane itself maintained a constant heading and climb rate for more than 2 minutes. The Safety Board believes that it would be improbable for the airplane to maintain a constant heading and climbing flightpath unassisted by lateral and longitudinal control corrections.

The Piper pilot's primary flight instructor stated that the pilot used the "wing leveler" when looking at maps or charts, or when doing other in-cockpit activities. Had the "wing leveler" been engaged at 5,500 feet and the pilot disabled, the airplane would have maintained heading and, depending on how accurately the pilot had trimmed out the elevator forces to maintain the climb rate, could have reached collision altitude unassisted. However, the recorded radar data showed two turns in the Piper airplane% track. About 1148:14, a left turn that corresponded to about 5° bank was started. The turn lasted about 20 seconds and, thereafter, the airplane returned to wings-level flight. The second, a slight turn to the right corresponding to a 5° bank, began at 1149:50 and ended about 1150:05 when the airplane was again returned to wings-level flight. At the end of the second turn, the airplane would have climbed to about 5,500 feet. The data from the flightpath seem consistent with the control inputs of a conscious pilot.

Two additional points bear on this issue. First, there is no evidence that an emergency radio call was made from the Piper. Second, the occupants of the Piper were found in the wreckage with their seatbelts fastened. If the pilot had suffered a major medical problem, the Safety Board believes that one or both of the remaining occupants would have unfastened their seatbelts and possibly the pilot's seatbelt while attempting to assist him. The evidence points strongly to the fact that there was no disturbance in the cockpit and that the flight was proceeding normally when the collision occurred. The Safety Board concludes that the weight of the evidence showed that the pilot of the Piper did not suffer a heart attack and that the Piper's entry into the Los Angeles TCA was not caused by any physiological disability of its pilot.

Although the pilot of the Piper had flown about 5.5 hours in the Los Angeles area, the Safety Board could not establish the routes of those flights and therefore how familiar he might have been with the boundaries of the TCA in the vicinity of Long Beach and the Seal Reach VORTAC. However, the pilot was not a total stranger to the Los Angeles TCA and his discussions with other pilots demonstrate that he was well aware of the flight procedures required either to enter the TCA or to avoid it. The pilot discussed the route to Big Bear with another pilot, who advised him on how to stay out of the TCA. This pilot was intimately familiar with the area's freeway complex and relied on these underlying highways as landmarks to denote the geographical boundaries of the various segments of the TCA and resultant altitude requirements. In their discussion of the route to Big Bear, this pilot mentioned using freeways to stay clear of the TCA; however, the pilot of the Piper was not as familiar with these freeways and therefore might have used the wrong freeways instead of relying on the more prominent checkpoints, such as Disneyland and the Anaheim Stadium, to identify his position in order to control his altitude and avoid entering the TCA.

The pilot of the Riper was described as methodical and professional in his approach to flying, and as a pilot, more inclined to navigate by visual reference to the ground than to use navigational radio aides. The fact that he tried to obtain advice concerning the Los Angeles area and the TCA before the flight and had purchased a Los Angeles Terminal Area Chart, which was found opened in the cockpit wreckage, tend to confirm this assessment of his approach to flying. Given these facts, the Safety Board believes that it is extremely unlikely that he would intrude deliberately into the TCA. In the absence of any positive evidence to the contrary, the Safety Board concludes that the pilot intended to avoid the TCA but that he probably misidentified his navigational checkpoints and entered the TCA inadvertently.

The entry of the Piper pilot into the TCA stripped his airplane and flight 498 of the precise protection the TCA was designed to provide. Its entry into this prohibited airspace created an exposure to risk that should never have existed and, therefore, the Safety Board believes that the intrusion into the TCA was a causal factor in the ensuing accident.

Before the accident, the Los Angeles TRACON forwarded TCA intrusion cases to the Los Angeles FSDO for enforcement action at a rate of about one per month; after the accident, the rate increased to about 10 per month. The pre-accident rate may be indicative of the difficulties involved in detecting, tracking, and identifying a TCA intruder cited in the TCA Task Group's report to the Administrator. However, the post-accident increase in the rate under the same conditions that existed before the accident indicates a less-than-efficient pre-accident effort by personnel in the Los Angeles TRACON to detect and identify TCA intruders. In addition, the TCA Task Group's report also concluded that, nationwide, "many, if not most, violations observed by the FAA are not referred for enforcement action because the aircraft and the pilot involved cannot be identified."

The Safety Board believes that if the TCAs are to continue to provide the protection they are designed to provide to the aviation community, the FAA must ensure that the regulations supporting this protected airspace are well known within that community, and most important, that it can and will enforce these regulations. The Safety Board believes that the recommendations in the Administrator's TCA improvement plan, if placed in effect promptly and executed properly, will inform the aviation community of the FAA's intent to maintain and enforce the integrity of the TCA airspace.

The evidence indicated that the Piper pilot was aware of the Los Angeles TCA, the regulations regarding its use, and the need to avoid it. Since there is no evidence that he entered the TCA in defiance of the prohibitory provisions of the relevant regulations, the Safety Board concludes that the enforcement efforts of the Los Angeles TRACON to support the TCA was not a casual factor in this accident.

2.4 The ARTS III

Without mode C altitude information; the AR-l controller could not determine whether VFR code 1200 targets displayed within the horizontal boundaries of the TCA were within its vertical limits and, therefore, actually within it. Although he could assume that since these targets had not been cleared to enter they were not in the TCA, and therefore, not a factor to the airplanes under his control within the TCA, he testified that he would not make that assumption. He testified that, workload permitting, he would provide a traffic advisory concerning any target he considered to be a factor to any airplane under his control and, thus, had he seen a VFR code 1200 target at the Piper's location, he would have provided a traffic advisory to flight 498. He testified that he did not provide that advisory because the Piper's target "was not displayed," and further that it was his "belief that he was not on my radar scope". Therefore, the Safety Board sought to determine what targets, if any, were displayed on the AR-l controller's display at the time of the collision, and especially whether the Piper radar target was displayed.

The evidence showed that an overloaded ARTS III computer will not display targets in excess of its display storage capacity. As a display overload condition occurs, the computer will print out messages announcing it is overloaded and identify the types of targets it is not displaying. None of these messages were printed at or before the time of the accident, nor any message that the computer was within 85 percent of its tracking capacity. In addition, none of the TRACON's controllers reported the occurrence of "flicker", which indicates the onset of display overload. The evidence was conclusive that, during the time interval encompassing the collision, the ARTS III computer was not overloaded and was still placing target data into its tracked and untracked target buffers. Of greater significance is the fact that there was no aspect of the ARTS III computer hardware or software that would supress the display of a tracked or untracked target from the controller's displays.

The recorded radar data showed that beacon returns for both flight 498 and the Piper had been received, processed by the ARTS III Data Acquisition System, processed by the ARTS III computer, and presented to the display. When recorded radar data were inserted into the Retrack Program Computer, which was programmed to perform the functions of the Los Angeles TRACON's I/O Processor, the alphanumeric symbols representing the Piper and flight 498 were reproduced on the display. Since the DEDS used during the retrack test was configured as was the AR-l controller's DEDS at the time of the accident, the alphanumerics presented on the retrack display were identical to those that would have been presented on the AR-l controller's display. The AR-l controller testified that numerous other VFR code 1200 targets were on his display at the time of the collision and the Retrack Program Computer displayed what were probably these targets. Since there was no functional way the AR-l controller could have selectively removed any one of several VFR targets from his display, and since there was no functional reason why targets that have been processed by the I/O Processor for display would not be displayed, the Safety Board concludes that the alphanumeric data recovered from the recorded radar data tapes were displayed on the AR-1 controller% display at the time of the accident.

The Retrack Program also duplicated the "stitching" movement of the targets. When the progress of the Piper's target and flight 498's target across the retrack display was monitored, it was obvious that, regardless of "stitching," their proximity to each other would have required the controller, had he observed them and had workload permitted, to issue a traffic advisory to flight 498. Since the Safety Board has concluded that, at the least, the alphanumeric symbology denoting the location of the Piper was displayed on the AR-l controller% display, the Safety Board therefore sought to determine why the AR-l controller did not observe the Piper's target.

2.5 ATC Procedures

The procedures contained in the Controllers Handbook require ATC controllers to prioritize the services they provide. First priority must be given to IFR airplanes, to which controllers must provide traffic separation service. The training given to controllers at the FAA Academy in Oklahoma City, Oklahoma and during on-the-job facility training 'emphasize this priority. Thus, except for an aircraft safety alert, a traffic advisory is an additional service to be provided "workload permitting," and, "contingent only upon higher priority duties...."

With regard to the Aircraft Conflict Alert advisory, the Handbook limits the application 0f that procedure to situations where the controller is "aware of another aircraft at an altitude which you believe places them in unsafe proximity." The Piper did not provide any altitude data to the controller and therefore, did not present a condition that required the controller to give this type of advisory. Although the AR-l controller said he intended to provide traffic advisories concerning the type traffic the Piper airplane represented, the Safety Board believes that the reason he did not observe its target may have been caused by his attempt to adhere to the priorities and procedures he had been taught. Consequently, the Safety Board concludes that the ATC procedures were causal to the accident in that they set the stage for the controller to "overlook" or "not see" the Piper's target on his display.

The AR-1 controller's radio conversations with the various airplanes to which he was providing services indicated strongly that his attention was directed toward the area east of L.A. International wherein traffic was descending to land. At 1150:46, he advised flight 496 of traffic at "ten o'clock" and then watched it pass behind the flight. He testified that after he saw the traffic pass flight 498, he "saw no traffic along its projected route of flight that would be a factor". It would appear from his testimony that the controller had developed an expectation that there was no traffic between flight 498 and the airport. Between 1151 and 1152, the traffic situation changed. During this time, N1566R's pilot called and requested flight following along a route to Van Nuys at 4,500 feet. At the same time, the controller was told that flight 498 would now land on runway 24 right.

Although the AR-l controller did not assign a discrete VFR transponder code to N1566R until 1152:04, it was obvious, based on his insertion of N1566R's identification into the ARTS III at 1151:37 and his testimony that he was concerned that N1566R was going to enter the TCA, that its route of flight would take it across the landing approaches to L.A. International, and that he would have to provide flight following services. Once the controller made that decision, N1566R would have to be treated as an IFR airplane for the purpose of separation while it was in the TCA. The controller testified that during this period he scanned along N1566R's proposed route of flight to try to locate its VFR target return, and he also looked at the adjacent AR-2 display to see if any traffic inbound to runways 24L and 24R would affect flight 498. Given these conditions, it was entirely possible that his scan of his display may have focused on the area east of the airport and, in addition, when he returned his scan to the flight 498's radar return to check its projected flightpath and groundspeed toward the landing runway his scan may have concentrated more on the groundspeed readout in its data block than anything else.

Perception, stress, and motivational research studies show a relationship between workload and operator performance. At some point, workload can increase so that it physiologically or psychologically overloads the operator to the extent that relevant cues will be unintentionally missed or disregarded. This causes operators to tunnel or narrow their perception or attention. Under high workload situations, it has been demonstrated repeatedly that the operator will focus on the primary or **"priority"** tasks, and his attention to secondary tasks will deteriorate. 11/

While in this case, the AR-l controller's total workload was neither numerically large nor did it suddenly increase significantly, the change of runways for flight **498,** coupled with the sudden appearance of **N1566R,** required a shift in his focus of attention and brought additional airplanes for consideration into his separation tasks. In addition, his admonition at **1152:36** to the pilot of **N1566R** concerning his intrusion into the TCA seemed to indicate that the controller was annoyed by the additional tasks imposed on him by the abrupt intrusion. Consequently, evidence indicates that the controller's scan of his display was focused almost exclusively on an area that did not include the location of the Piper's target. The Safety Board concludes that this may have been why he did not see the Piper's radar target.

The ATC Handbook required the controller to "give first priority to separating aircraft. . . ." Therefore, except for certain participating VFR aircraft, the major amount of the controller's traffic separation duties were directed to IFR aircraft which had been assigned appropriate discrete transponder codes and had presented on the **cntroller's** display a full data block in addition to their primary radar returns, beacon control slashes, and appropriate alphanumeric symbols. Furthermore, even participating VFR aircraft would have been assigned an appropriate discrete VFR transponder code, indentified in the ARTS III computer for tracking, and, thus even these aircraft would have presented more data on the controller% display than an untracked code 1200 VFR target. **(N1566** was handled in this manner.) The Safety Board. believes that the priorities placed on the controller to provide traffic separation to these type aircraft could have lessened his awareness to the presence of the code 1200 VFR targets around the periphery of the area or areas containing the higher priority targets to which provide separation protection. Consequently, he might not perceive a developing threat, posed by a code 1200 VFR target to one of his priority targets until they are in close proximity, or he might not, particularly if his assessment of the information presented on his display is affected by other factors such as the presence of a positive control type airspace, perceive the developing threat at **all** and thus not **"see"** the target. The Safety Board concludes this prioritizing procedure may have been, particularly when a code 1200 VFR target without accompanying altitude information was located within the lateral confines of the Los Angeles TCA, a reason why the controller did not perceive or see the Piper's radar target.

With regard to the TCA, the Safety Board is also concerned that the depiction of numerous VFR non-mode C-equipped aircraft within the horizontal confines of the TCA may, unintentionally, encourage controllers to form certain expectations. It is obvious that **all** of these airplanes cannot be within the verticaland horizontal confines of the TCA. Further, since VPR traffic must, by FAA regulations, avoid entering the TCA without an ATC clearance, a strong presumption exists that- the VFR traffic displayed within the horizontal confines of the TCA is not within its vertical confines and therefore no threat to aircraft legitimately within the TCA. Therefore, notwithstanding the AR-l **controller's** assertion that he would issue traffic advisories for all such targets even though he had not cleared them into the TCA, the Safety Board believes that the controller may have unconsciously decided that the airplane represented by the Piper's radar target was not within the vertical confines of the TCA and **therefore,** was no threat to flight 498. The controller might then have decided without conscious realization that he

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11/ Easterbrook, J.A. Effects of emotion on cue utilization and organization of behavior. Psychological Review, 1959.

had done so, to forego issuing a traffic advisory to flight 498 concerning the Piper airplane's target. In that regard, the Safety Board commends the FAA's present rule-making effort to require that all aircraft to be operated within 30 nmi of a TCA airport be equipped with and use a mode C altitude encoder. The addition of altitude information to the VFR codes will enable controllers to identify those VFR aircraft that threaten controlled traffic within the TCA. It will also enhance the FAA enforcement program, since controllers will be able to recognize aircraft that enter the TCA without proper clearance and to begin the procedures required to track and identify the intruder.

One other factor may have contributed to the AR-l controller's failure to see the Piper's radar return. During the September 3 flight inspection, the flight inspection airplane's primary target on the display was unusable for at least six revolutions of the radar antenna (about 30 seconds) before the airplane reached the midair collision point. Although the refractive index was greater on the day of the flightcheck than it was on the day of the accident, it is possible that the primary radar return from the Piper airplane was either not displayed or its persistence on the display was compromised during the critical period of time when the AR-l controller was adjusting flight 498% airspeed. Given the configuration of the TRACON's lo-channel decoder, if the primary return did not appear, the only evidence of the Piper's position would have been the ARTS III-generated alphanumeric triangle, which is much smaller than a VFR aircraft primary radar return. Since all other VFR aircraft in other areas of the display would have been marked by the larger primary return, it was also possible that the AR-1 controller, not realizing that the Piper's primary radar return was no longer being displayed, would have been relying on its presence to mark traffic during his scan of the display. Given his concentration on the area to the east of the airport during this critical time, it is possible and understandable that he might miss the far less prominent alphanumeric triangle when he scanned that area of his display.

On March 11, 1987, the ASR-4 radar reception of the flight inspection airplane's primary target was better than on September 3. On March 11, the refractive index gradient in the Los Angeles area was not as great as it was on September 3 and, in the area of the accident, the primary target was missed once and its target strength was always usable. On the day of the accident, the refractive index gradient was greater than it was on March 11, but less than on September 3, and the ASR-4 should have performed better on August 31 than it did on September 3. Given these data, the Safety Board cannot conclude that the Piper% primary radar return either did not appear. or that its persistence was decreased to the point that it was unusable; however, it also cannot entirely rule out either possibility. Therefore, the Safety Board also believes that the decision of the managers of the TRACON to configure the lo-channel decoder as described herein may have decreased the prominence of the Piper's radar return. The Safety Board does not believe that the evidence supports the assertion of the TRACON's . facility chief that configuring the decoder to provide beacon control slashes in addition to the primary radar return for code 1200 aircraft would produce unacceptable clutter on the facility displays. The beacon control slash is longer than the primary target and the alphanumeric symbol which is superimposed over the beaeon control slash. Thus, the use of the beacon control would provide a slightly larger and more intense radar return.

One of the purposes of the transponder-beacon system is to provide a target for controllers when the primary target is unreliable. If, in this instance, the primary target either was missed or its persistence compromised, the presence of a beacon slash would have denoted prominently the location of the Piper airplane. In addition, a beacon can be used for traffic separation; the ARTS III alphanumeric symbol cannot. The configuration of the 10-channel decoder on the day of the accident removed a redundant display feature from the ATC environment.

The decreased prominence of the Piper's target on the controller% display as a consequence of the standard configuration of the equipment in the Los Angeles TRACON may have been a factor in the controller's failure to observe the target. The decreased target prominence was a consequence of the facility decision to inhibit display of the analog beacon return for VFR targets whose transponders were set on code 1200. This decision was reportedly implemented to reduce the clutter on the display which would result from the large number of VFR aircraft in the Los Angeles basin. The Safety Board acknowledges that the positive and negative aspects of displaying code 1200 beacon slashes must be considered by the controllers and facility managers in the establishment of procedures and equipment set up.

Given the evidence concerning the radar and ARTS III presentation and the controller's actions, the Safety Board concludes that the positions of the Piper airplane were depicted on the AR-l controller's display by, at the least, an alphanumeric triangle, but that 'the controller did not observe the Piper's radar target. The Safety Board has cited the following three factors that could have caused the controller to overlook the Piper's radar return: the possible distraction of his attention from the critical area of his radar display caused by the projected entry of N1566R into the TCA and the change of landing runways for flight 498; the possibility that the controller may have unintentionally discounted the non-mode C VFR radar return of the Piper as a threat because it was located within the lateral confines of the TCA; and the possibility that the primary radar return of the Piper either did not appear on 'his display or the strength of the return was compromised by atmospheric interference. The evidence does not permit the Safety Board to select which factor or combination of factors caused this to occur. Therefore, the Safety Board concludes that the failure of the controller to observe the Piper's radar target could have been caused by any one of the three cited factors, or by a combination of any two these factors, or by all of them. As a result, the controller did not provide a timely traffic advisory alerting flight 498 to the presence of and relative position of the Piper PA-2 8.

The failure of the controller observe the radar return of the Piper and, thus, to provide a timely traffic advisory to flight 498 placed that flightcrew in the same position as all other VFR pilots flying in visual meteorological conditions (VMC); their ability to see and avoid other airplanes depended on their alertness, the quality of their scanning procedures, and the conspicuity of the targets they were seeking to acquire.

The Safety Board cannot state with certainty that this collision would have been prevented by a timely traffic advisory; midair collisions have occurred after pilots have received relevant ATC traffic advisories. 12/ However, a traffic advisory would have alerted the Aeromexico pilots of a specific threat and provided a relative bearing from their airplane along which they could concentrate their attempts to see the threatening airplane. The Safety Board believes that had this advisory been provided, it would have increased the Aeromexico flightcrew's chances of seeing the Piper in time to avoid the collision. Although the Federal Aviation Regulations 13/ required the Aeromexico flightcrew to maintain continous vigilance to see and avoid other aircraft, a timely traffic advisory would have increased their ability to exercise this responsibility efficiently. Therefore, since the failure to provide this warning decreased the Aeromexico flightcrew's chances to locate the Piper, the Safety Hoard concludes that this failure was a contributory factor in the accident sequence.

12/ Pacific Southwest Airlines Boeing 727 and a Cessna 172, San Diego, California, Septe mber 2 5, 197 8 (NTSB-AAR-79-5).

13/ 14 CFR Part 91.67(a) states in part, When weather conditions permit, regardless of whether an operation is conducted under Instrument Flight Rules or Visual Flight 'Rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft in compliance with this section."

2.6 See and Avoid

Based on the cockpit visibility study (appendix G), both airplanes were within the pilot's fields of vision for at least 1 minute 13 seconds before the collision-but with certain limitations. The visibility study showed that the Piper was visible through the center windshield of the DC-9 as viewed from the first officer's seat, and about half the plots showed that the Piper was located in the first officer's monocular vision field. In addition, since the captain was making all air to ground radio communications, the Safety Board concludes that the first officer was flying the airplane. Over half of the position plots for the Piper airplane show that it was visible to the captain through windshield and was within his normal binocular vision field.

The Safety Board determined that the person occupying the right seat in the Piper was not a pilot and had never received scan training. Therefore, for this analysis, the Safety Board assumed that only the pilot was or could have scanned for other airplanes. Based solely on the relative size of the two airplanes, the Probability of Visual Acquisition Graphs (appendix H) show that the Piper pilot had a better chance of seeing the DC-9 than the Aeromexico flightcrew had of seeing the Piper. However, the location of the DC-9, as depicted on the Piper visibility study, showed that the DC-9 was visible through the Piper's right windscreen and near the outer limits of a left-right scanning pattern. Since the Safety Board cannot assume that any of the passengers would have been involved in an active scan for airplanes, the location of the DC-9, despite its greater size, would have reduced the Piper pilot's ability to see it. Further, given the available evidence, the Safety Board cannot reach any conclusion concerning his alertness to the conduct and maintenance of an active scan for other airplanes.

Aeromexico regulations do not contain specific procedures limiting cockpit conversation and prohibiting flight attendants from entering the cockpit during critical phases of flight as do those for U.S. air carriers. However, its regulations do require the cockpit door to be closed during flight and they state specifically who may occupy the cockpit jumpseat. The available evidence does not permit any conclusions that the flightcrew's attention to required duties was compromised during the descent.

Based solely on the location of the Piper on their airplane's windows and windshields, the Aeromexico flightcrew should have had an almost unobstructed view of the Piper PA-28. Although the first officer was flying the airplane, the autopilot, in accordance with company policy and procedures, should have been engaged, thus freeing him from some of the duties associated with hand-flying the DC-9. Of greater significance was the fact that the Piper was approaching the DC-9 from the non-flying pilot's side with less than a 30° offset to the left; thus, the Piper was in an area where the captain's natural scan and attention should have been focused. Mitigating against these advantages was the smaller size of the Piper and the fact that it was, visible to the first officer only through the center windshield. In addition, because the airplanes were on a collision course, the relative motion of the Piper would presumably been minumal and, therefore, it would have been more difficult to detect.

In addition to the limitations imposed by cockpit structure, the physiological capability of the human eye to identify targets also limited the ability of the pilots to see the other airplane. Data indicates that, as a minimum, targets should subtend a visual angle of 0.2° (12 minutes) of arc to reasonably ensure accurate recognition. 14/ The Piper would have subtended a visual angle of 0.2° of arc when it was a little over 1 nmi away or 15 seconds before the collision. The DC-S would have subtended this visual angle when it was about 6 nmi away or about 1 minute 23 seconds before the collision.

14/ Van Cott, H. and Kinkade, R "Human Engineering Guide to Equipment Design," Revised Edition; American Institute for Research, Washington, D.C., 1972.

The visual acquisition charts further illustrate some of the difficulties pilots face in seeing and avoiding other targets. To be effective, the pilot must see the other aircraft in time to initiate and complete an evasive maneuver. FAA Advisory Circular (AC) 90-48C, which is based on militaryderived sources, states that the total time necessary for a pilot to see an object, to recognize it as a potential midair target, and then to execute an evasive maneuver is 12.5 seconds. The TCAS resolution maneuver is supplied to the pilot between 25 to 30 seconds before the airplane reaches the projected collision point. Given these data, the Safety Board believes that, for this discussion, 15 seconds would be a reasonable time for a pilot to recognize a potential target and execute an evasive maneuver.

The visual acquisition chart indicated that the Piper pilot had an 80 percent probability of seeing the DC-9 at 15 seconds before the collison. With both pilots of the DC-9 looking, the probability of their sighting the Piper airplane 15 seconds before the collison was 30 percent and with one pilot looking, the probability diminished to 15 percent. With regard to "see and avoid," the evidence indicated that the pilot of the Piper had a high probability of sighting and avoiding the DC-9, whereas the probability of the Aeromexico flightcrew sighting and avoiding could only be characterized as marginal, at best. However, while these data indicate that "see and avoid" is not a totally acceptable concept, other evidence indicates that its viability cannot be dismissed summarily.

During 1985 and 1988, pilots reported a total of 1,598 near midair collisions (NMAC) to the FAA. 15/ During this 2-year period, 341 NMACs were classified critical, 887 potential, and the remainder were either adjudged no hazard, "unclassified," or "open." The 887 potential NMACs indicate that pilots do see and do avoid other airplanes while flying in visual flight conditions.

Regardless of the above considerations, both airplanes were operating in visual flight conditions and therefore were required by regulations to see and avoid each other; however, in this case, their failure to do so must be evaluated in context with the limitations placed on the pilots by the angles of closure, the size of the targets, the conspicuity of the targets, and the physiological capabilities of the human eye to accomplish this task.

The charts showing probability of visual acquisition also demonstrate the value of alerting pilots to the presence and location of a collision threat. The chart indicates that had a TCAS alert been provided to the DC-9 pilots, the probability of acquisition with both pilots looking would have increased from 30 percent to 95 percent. However, the 95 percent probablilty of acquisition was based on a TCAS alert that provided the target's relative hearing, range, and altitude. In this instance, the Aeromexico flightcrew would have been provided only the Piper's relative range and bearing. While the absence of altitude information would have made the pilot's task of visually acquiring the target more difficult, the probability of acquisition still would have exceeded that of an unalerted flightcrew.

In conclusion, the Safety Hoard has recommended the development of TCAS and the establishment of TCAs as a means to lessen'the risk and possibly to eliminate the occurrence of midair collisions near major air traffic hubs. The evidence shows that, first, had flight 498 been equipped with a TCAS, the accident might not have occurred and second, had the Piper been. mode C-equipped, the collision probably would have not occurred. The Safety Hoard believes that the 'TCAS development program must be expedited and the installation of TCAS must be mandatory on all air carrier and

15/ Selected Statistics Concerning Pilot Reported Near Mid-Air Collisions; U.S. Department of Transportation; FAA; Office of Aviation Safety; Safety Analysis Devision.

commuter airline aircraft; at the very least. In this regard, the Safety Board is also gratified to note that Piedmont Air Lines has begun airborne testing of the TCAS II during line operations and that United and Northwest Air Lines will begin similar programs in the near future.

The Safety Board also believes that the TCA remains a very viable concept for decreasing the midair collision risk at major airports. The program to strengthen these restricted airspaces, as approved by the FAA Administrator (appendix F), addresses many of our concerns. The FAA's June 11, 1987, NPRM addresses a requirement for mode C altitude reporting transponders within a 30-nmi radius of the primary airport in all TCAs. The Safety Board strongly supports this action and, in fact, believes that even more stringent transponder requirements should be imposed. The Safety Hoard believes that mode C transponders should be required for all aircraft sharing airspace with air carrier aircraft that will eventually be equipped with TCAS. This could be accomplished to a large extent if the requirements for entry into an Airport Radar Service Area were strengthened to include transponder mode A and C requirements.

The Safety Board believes that the potential for midair collisions between VPR and IFR aircraft will continue to exist so long as the avoidance of such collisions totally depends on the alertness of pilots and air traffic controllers without supplementary features to warn of impending conflict. The implementation of the conflict alert feature in en route and terminal radar control computers has undoubtedly contributed to the avoidance of collisions between two IFR aircraft. The en route Air Route Traffic Control Center (ARTCC) systerns are being expanded to include conflict alert for transponder-equipped VFR targets as well as discrete IFR targets. The Safety Board understands that present terminal area control computer capacity is inadequate for such enhancements and that future implementation of VFR conflict alert within the terminal area is not planned to be implemented until the mid 1990s as a feature of the Advanced Automation System (AAS). However, the Safety Board believes that the software computer logic for terminal area conflict has been developed and could be implemented if additional processing capability were added to existing ARTS IIIA equipment. The procurement of additional processors would probably infringe on other FAA priorities and would be viewed as an interim measure to the ultimate installation of the AAS. Nonetheless, the Safety Board believes that the benefit of expediting VFR conflict alert features in terminal computers would merit such expenditure.

The facts and circumstances of this accident demonstrated the necessity of providing both controllers and pilots with automated warning systems that can assist them in avoiding midair collisions. These systems should alert the ATC controller of an impending traffic conflict and the pilots" system should alert them to the presence and location of any aircraft that poses a collision threat to his aircraft. If either the pilots or the controller had available this type of equipment to assist them, this collision might have been avoided. Therefore, the Safety Board concludes that the lack of automated redundancy to assist the pilot and controller was a causal factor in this accident.

CONCLUSIONS

3.1 Findings

1. The airplanes collided at a 90° angle, at an altitude of about 6,560 feet, and in visual meteorological conditions. The collision occurred inside the Los Angeles TCA.

2. Roth pilots were required to see and avoid the other airplane. There was no evidence that either pilot tried to evade the collision.

3. The pilot of the Piper was not cleared to enter the Los Angeles TCA. His entry was inadvertent and was not the result of any physiological disablement.

4. The unauthorized presence of the Piper in the TCA was a causal factor to the accident.

5. The positions of the Piper were displayed on the AR-l controller's display by, at the least, an alphanumeric triangle; however, the Piper's primary target may not have been displayed or may have been displayed weakly due to the effects of an atmospheric temperature inversion on the performance of the radar. The analog beacon response from the Piper's tranponder was not displayed because of the equipment configuration at the Los Angeles TRACON.

6. The AR-l controller stated that he did not see the Piper's radar return on his display, and, therefore, did not issue a traffic advisory to flight 498. His failure to see this return and to issue a traffic advisory to flight 498 contributed to the occurrence of the accident.

7. The Los Angeles TRACON was not equipped with an automated conflict alert system which could detect and alert the controller of the conflict between the Piper PA-28 and flight 498.

3.2 Probable cause

The National Transportation Safety Board determines that the probable cause of the accident was the limitations of the air traffic control system to provide collision protection, through both air traffic control procedures and automated redundancy. Factors contributing to the accident were (1) the inadvertent and unauthorized entry of the PA-28 into the Los Angeles Terminal Control Area and (2) the limitations of the "see and avoid" concept to ensure traffic separation under the conditions of the conflict.

4. RECOMMENDATION

4.1 Recommendations Addressing Midair Collision

Since 1967, the Safety Board has issued 116 recommendations as a result of its investigations, special studies, and special investigations of midair or near midair collisions. A review of these 116 recommendations identified 56 that are pertinent to the accident at Cerritos (appendix H).

The 56 recommendations suggested changes and/or improvements that the Safety Board believed would decrease the midair collision risk. The areas addressed in these recommendations included among others: radio communication procedures; development of ATC procedures to provide separation between high-and-low performance aircraft in high-density terminal areas; improvement of ATC radar capability; improvement of aircraft conspicuity, particularly the development and installation of anti-collision light systems and the requirement to use these lights day and night; and the development of airborne collision warning systems.

On November 4, 1969, the Safety Board convened a public hearing to investigate the subject of mid-air collisions. As a result of the hearing, 14 safety recommendations were sent to the FAA. Recommendations A-70-5 through -15 were sent to the FAA on February 22, 1971. These 14 recommendations addressed the area cited in the previous paragraph.

During this 19- year period, the remainder of the recommendations sent to the FAA have continued to stress these areas of concern and, where warranted by facts developed during other investigations, to amplify and reiterate matter and materials contained in some of the earlier recommendations. The history of these 56 recommendations and the actions taken by the FAA in response to them is contained in detail in appendix H.

As a result of this accident investigation and a review of the FAA's ongoing activities, the Safety Board reiterates the following recommendations to the FAA:

> Expedite the develop ment , operational evaluation, and final certification of the Traffic Alert and Collision Avoidance System (TCAS) for installation and use in certificated air carrier aircraft. (Class II, Priority Action) (A-65-64)
>
> Amend 14 CFR Parts 121 and 135 to require the installation and use of Traffic Alert and Collision Avoidance System (TCAS) equipment in certificated air carrier aircraft when it becomes available for operational use. (Class III, Longer Term Action) (A-85-65)

In addition, the Safety Board recommends that the FAA:

> Implement procedures to track, identify, and take appropriate enforcement action against pilots who intrude into Airport Radar Service Areas (ARSAs) without the required Air Traffic Control (ATC) communications. (Class II, Priority Act ion) (A-87-96)
>
> Require transponder equipment with mode C altitude reporting for operations around all Terminal Control Areas (TCAs) and within an Airport Radar Service Area (ARSA) after a specified date compatible with implementation of Traffic Alert and Collision Avoidance System (TCAS) requirements for air carrier aircraft. (Class III, Longer Term Action) (A-87-97)
>
> Take expedited action to add visual flight rules conflict alert (mode C intruder) logic to Automated Radar Terminal System (ARTS) III A systems as an interim measure to the ultimate implementation of the Advanced Automation System (AAS). (Class III, Longer Term Action) (A-87-98)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

/s/ JAMES L. KOLSTAD
Member

Jim Burnett, Chairman, filed the following dissenting statement regarding probable cause and contributing factors:

The National Transportation Safety Board determines that the probable cause of the accident was the limitations of the air traffic control system to provide collision protection, through both air traffic control procedures and automated redundancy. Contributing to the accident was the inadvertent and unauthorized entry by the pilot of the PA-28 into the Los Angeles terminal control area and his failure to see and avoid the DC-9 prior to the collision.

/s/ JIM BURNETT
Chair man

July 7, 1987

5. APPENDIXES

APPENDIXA

INVESTIGATION AND HEARING

L Investigation

The Safety Board was notified of the accident at 1520 eastern daylight time on August 31, 1986. Investigators from the Safety Board's Los Angeles, California, Field Office were on the accident scene within 30 minutes of the accident and cooperated with local law enforcement agencies in securing the accident scene. A team of investigators was dispatched from Washington, D.C., and arrived on the scene at 2200 Pacific daylight time on August 31. Investigative groups were formed for operations, air traffic control, witnesses, meteorology, survival factors, structures, powerplants, systems, maintenance records, flight data recorder, cockpit voice recorder, airplane performance, and human performance.

The parties to the investigation were the Federal Aviation Administration, Aeromexico Air Lines, the International Federation of Air Line Pilots Association, Piper Aircraft, McDonnell Douglas, the Aircraft Owners and Pilots Association, and the Flight Attendants Association of Mexico.

A representative of the Director General of Civil Aviation of Mexico was appointed as the accredited representative of the government of the Republic of Mexico and participated in the investigation.

2. Public Hearing

A 4-day public hearing was held in Los Angeles, California, beginning December 2, 1986. Parties represented at the hearing were the Federal Aviation Administration, Aeromexico Air Lines, the International Federation of Air Line Pilots Association, Piper Aircraft, the Aircraft Owners and Pilots Association, the Plight Attendants Association of Mexico, and the Professional Airways Systems Specialists.

A representative of the Director General of Civil Aviation of Mexico was appointed as the accredited representative of the government of the Republic of Mexico and participated in the public hearing.

APPENDIX B
PERSONNEL INFORMATION

Aeromexico Flight 498

Captain Antonio Valdez-Prom

Captain Antonio Valdez-Prom, 46, was employed by Aeromexico in October 1972. He held Mexican Airline Transport Pilot Certificate No. TPI 876 and U.S. Airline Transport Pilot Certificate No. 2314930 (issued under 14 CFR Part 61.7'7) with a McDonnell Douglas DC-9 type rating. The captain's first class medical certificate was issued April 9, 1986, with a limitation requiring that he wear glasses for near vision correction while exercising his airman's privileges.

Captain Prom qualified as captain on the DC-9 on January 20, 1984. His last proficiency check was completed March 12, 1986, and his last recurrency training was completed October 17, 1985. The captain had flown 10,641 hours, 4,632 of which were in the DC-9. During the last 90 days, 30 days, and 24 hours, the captain had flown 147 hours, 47 hours, and 4 hours, respectively.

The captain had been off duty about 16 hours before reporting for the accident flight. At the time of the accident, the captain had been on duty about 6 hours, about 4.7 hours of which were flighttime.

First Officer Jose Hector Valencia

First Officer Jose Hector Valencia, 26, was employed by Aeromexico in July 1984. He held Mexican Commercial Pilot Certificate No. 7657 and U.S. Commercial Pilot Certificate No.2355982 (issued under 14 CFR 61.77). The first officer's first class medical certificate was issued May 9, 1986, with the limitation that he wear glasses for near vision correction while exercising his airman's privileges.

First officer Valencia qualified as a DC-9 first officer on August 31, 1984. The first officer's last proficiency check was completed June 26, 1986, and his last recurrency training was completed December 12, 1985. The first officer had flown 1,463 hours, 1,245 of which were in the DC-9. During the last 90 days, 30 days, and 24 hours, the first officer had flown 184 hours, 53 hours, and 4.7 hours, respectively. He had been off duty about 56 hours before reporting for the accident flight. At the time of the accident, his on-duty and flight time were the same as the captains.

Piper PA-28-181, N4891 F

Pilot William K. Kramer

Mr. William K. Kramer, 53, held Private Pilot Certificate No. 534282891 with an airplane single engine land rating. Mr. Kramer's third class medical certificate was issued December 21, 1984, with a limitation requiring him "to wear corrective lenses while exercising the privileges of his airman certificate." Mr. Kramer had flown 231 hours. During the last 90 days, 30 days, and 24 hours, he had flown 2 hours, 0.6 hours, and 0.1 hours, respectively.

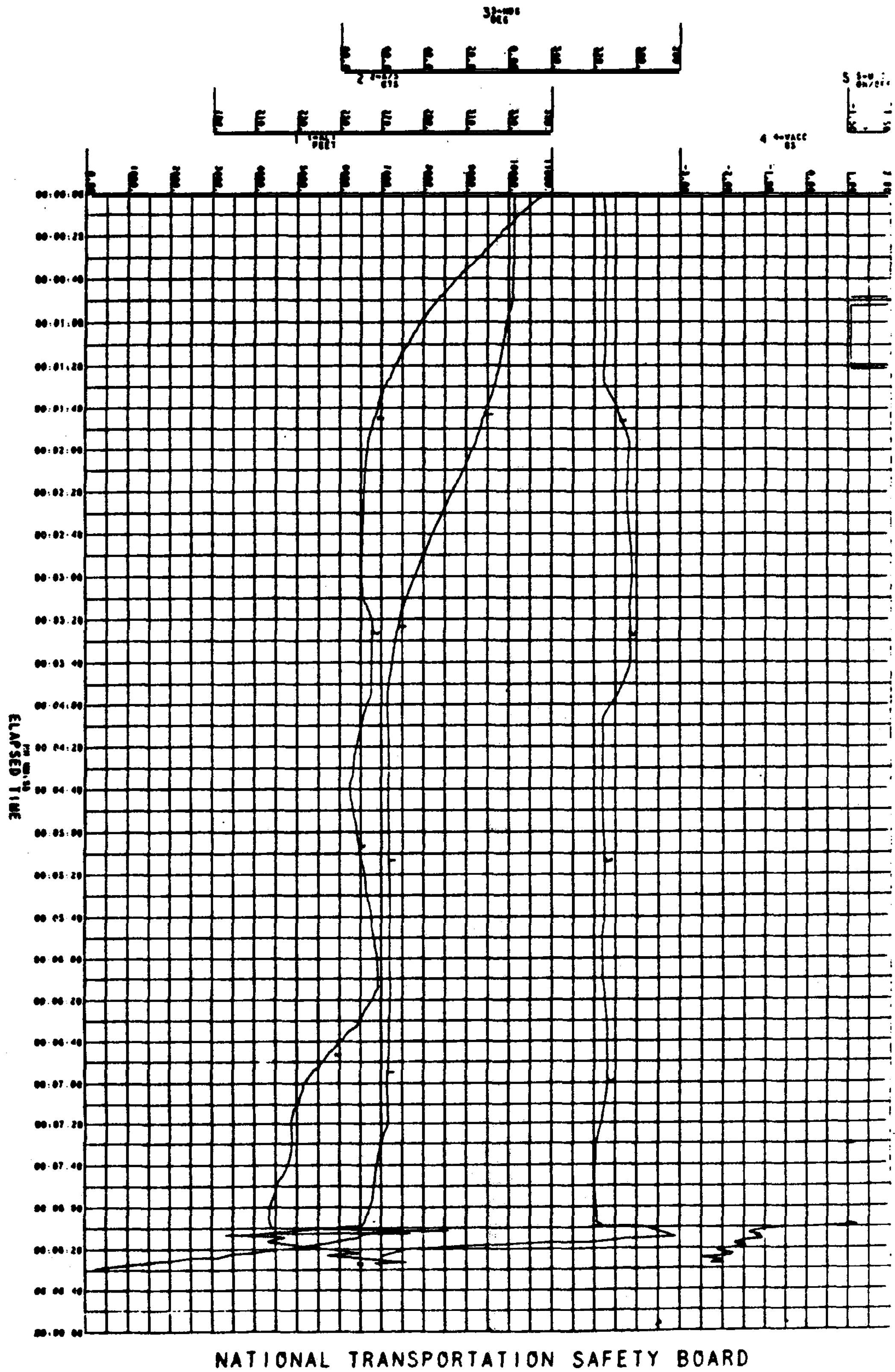
Air Traffic Control 'Personnel

Mr. Walter R. C. White

Mr. Walter R. C. White, 35, was employed by the FAA on December 1, 1980. His current medical examination was performed December 3, 1985.

The controller received his initial training at the FAA Academy, Oklahoma City, Oklahoma, and had worked at Brown Tower and Montgomery Tower in San Diego, California, and at Coast Tracon, El Toro Marine Corps Air Station, California, where he achieved Full Performance Level (FPL) Controller status. In December 1984, Mr. White transferred to the Los Angeles TRACON. At the time of the accident, Mr. White had not achieved the FPL rating at the TRACON because he had not been certified on the TRACON's arrival and departure coordinator positions.

APPENDIX C
FDR DATA, AEROMEXICO



NATIONAL TRANSPORTATION SAFETY BOARD
BUREAU OF TECHNOLOGY
WASHINGTON, D.C.

APPENDIX D
CVB TRANSCRIPT, AEROMEXICO

TRANSCRIPT OF A SUNDSTRAND MODEL V557 COCKPIT VOICE RECORDER S/N 1829, REMOVED FROM THE AEROMEXICO DC-9 WHICH WAS INVOLVED IN A MIDAIR COLLISION WITH A PIPER PA28-181, N9891F, AND AIR TRAFFIC CONTROL (ATC) RECORDING FROM LOS ANGELES TRACON AND COAST APPROACH CONTROL, NEAR CERRITOS, CALIFORNIA, ON AUGUST 31, 1986

CAM	Cockpit area microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voiee identified as First Officer
-?	Voice unidentified
UNK	Unknown
LA APP	Los Angeles TRACON Control (Approach Control)
COAST	Coast Approach Control
SKW222	Sky West Flight Two Two Two
WWM5225	Wings West Flight Five Two Two Five
WWM5083	Wings West Flight Five Oh Eighty Three
N1566R	Grumman November One Five Six Six Romeo
COMPANY	Aeromexico Company at Los Angeles International Airport
*	Unintelligible word
#	Nonpertinent word
@	Expletive deleted
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause

NOTE: All times are expressed in Pacific daylight time.

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		11:41:21 RDO-1	Coast Approach good morning, this is Aeromexico four ninety eight is level one zero thousand
		11:41:27 COAST	Aeromexico four ninety eight, Coast Approach good morning, roger one zero thousand proceed direct Seal Beach El Toro altimeter two niner niner air
		11:41:35 RDO-1	Direct Seal Beach altimeter two. niner niner six
11:42:35 CAM-?	* *		
		11:43:36 COAST	Arraexico four ninety eight, cross one zero miles southeast of Seal Beach at and maintain seven thousand
		11:43:44 RDO-1	One zero miles seven thousand Aeromexico four ninety eight
		11:44:54 RDO-1	Aeromexico four ninety eight is leaving one zero thousand for seven thousand
		11:44:58 COAST	Aeromexico four ninety eight roger

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-CROUNU COMMUNICATIONS TIME & SOURCE	CONTENT
11:46:15 CAM-1	They are runways twenty four right and ah left		
11:46:46 CAM	((Sound of LAX ATIS starts))		
		11:46:59 COAST	Aeraexico four ninety eight contact Los Angeleo Approach one two four point niner
		11:47:03 RDO-1	One two four point niner, good day
11:47:04 CAM	((ATIS ends))		
		11:47:05 COAST	Good day
11:47:23 CAM-2	---- depart ure		
11:47:24 CAN-1	One seven and twenty four		
		11:47:28 RDO-1	Los Angeles Approach good morning, this is Aeromexico four sixty four four ninety eight uh we're leaving, we're level one, correct ion seven thouaxnd

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
11:47:34 CAM-2	*		
11:47:37 CAM-1	Yes man		
		11:47:39 LA APP	Aeromexico four ninety eight Los Angeles Approach depart Seal Beach three two zero vector ILS two five left final approach, do you have Information Uniform
		11:47:46 RDO-1	Affirmative two five left runway
11:47:49 CAM	((Sound simular altitude alert tone))		
11:47:50 CAM-2	Two two zero for the runway ——		
		11:47:53 LA APP	Sky West two twenty two, traffic twelve o'clock four miles northbound, altitude unknown
		11:47:57 SKW222	Looking triple two
		11:47:59 LA APP	Wings West fifty two twenty five reduce speed to one seven zero

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-CHOUNU COMMUNI CAT IONS TIME & SOURCE	CONTENT
		If :48:03 WWM5225	Fifty two tventy five reducing to one seventy, we have the airport in sight
		11:48:06 LA APP	Thank you
11:48:09 CAM	((Sound of attendant call tone))		
11:48:14 CAM-2	Course two four nine ----		
11:48:15 CAM-1	Flight director up		
11:48:16 CAM-2	Flight director up		
		11:48:22 SKW222	And uh Approach was that fifteen hundred feet until advised landing for Sky West triple tvo
		11:48:27 LA APP	Sky West tvo twenty tvo correct
		11:48:29 SKW222	Thank you
11:48:31 CAM-?	•		

8

APPENDIX D

INTRA-COCKPIT

TIME & SOURCE	CONTENT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
11:48:52 LA APP	Wings West fifty tvo tventy five descend and maintain four thousand
11:48:57 WWM5225	Four thousand Wings fifty tvo tventy five
11:49:00 LA APP	Sky West tvo tventy tvo traffic ten o'clock two miles northveatbound is a Merlin at air thousand descending, he's fur tvo five left
11:49:08 SKY222	We're looking for him triple two
11:49:10 LA APP	Say that again air
11:49:11 SKW222	We're looking for him, he's not in sight yet
11:49:18 LA APP	Wings Yest fifty tvo twenty five, the Merlin you're folloving is tvo o'clock aud a mile and a half vest bound at three thousand, expect a turn to final in [illegible] i le
11:49:27 WWM5225	Fifty tvo tventy five looking for him, we still have the airport in sight

INTRA-COCKPII

TIME & SOURCE	CONTENT
11:49:41 CAM	((Sound of tone))

AIR-GROUND COMMUNICATION;

TIME & SOURCE	CONTENT
11:49:31 LA APP	Yea sir, I 'm gonna need you to see him, he's gonna pull out from under your nose in another aile or so
11:49:36 RDO-1	Aeraexico *
11:49:36 WWM5225	Roger
11:49:37 LA APP	Wings fifty two tventy five, turn left heading tvo five zero
11:49:40 COMPANY	(Aeromexico four nine eight go ahead)
11:49:41 LA AYP	Pifty tvo tventy five turn left heading tvo five zero
11:49:42 RDO-1	Thank you *
11:49:44 COMPANY	* • Aeromexico four ninety eight estimate fifteen minutes, you have assigned gate one hundred and nineteen and nineteen one one nine avaiting your arrival

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		11:49:44 WWM5225	Left two five zero fifty two twenty five
		11:49:46 LA APP	Wings West fifty two twenty five, do you see the traffic now at your twelve o'clock and a half mile westbound two thousand, descend and maintain three thousand
		11:49:52 RDO-1	Thank you (four one) eight nine
		11:49:54 WWM5225	Down to three thousand Wings fifty two twenty five no we don't got him
		11:49:57 LA APP	Sky West two twenty two contact Los Angeles Tower one two zero point niner five at Limma, good day
		11:50:01 SKW222	Bye bye
11:50:05 CAM	((Unintelligible female voice))	11:50:05 LA APP	Aeromexico four ninety eight, reduce speed to two one zero
		11:50:08 RDO-1	Two one zero four ninety eight

INTRA-COCKPIT

TIME & SOURCE	CONTENT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
11:50:10 LA APP	Wings fifty tvo tventy five, the traffic is now, correct ion, turn left heading tvo three xero, the traff ic'a at eleven o'clock and a mile
11:50:18 WWM5225	Two three zero fifty tvo tventy five roger and uh
11:50:22 LA APP	Understand you have him in sight
11:50:23 WWM5225	Yes sir, ve got him in a ight
11:50:24 LA APP	Wings West fifty tvo twenty five, follow that aircraft, he's for tvo five right, you're cleared for a visual approach to runvay tvo five left, contact Los Angeles Tover one tvo zero point niner five, good day
11:50:30 WWM5225	Cood day
11:50:39 LA APP	Wings West fifty eighty three, traffic twelve o'clock, four miles northbound, a lt it ude unknown

INTRA-COCKPIT

TIME & SOURCE	CONTENT
11:51:20 CAM-2	*

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
11:50:43 WWM5083	• fifty eighty three
11:50:46 LA APP	Aeromexico four ninety eight, traffic ten o'clock one mile northbound, altitude unknown
11:50:50 RDO-1	Roger four ninety eight
11:51:03 LA APP	Aeromexico four ninety eight reduce speed to one niner zero then descend and maint sin a ix t houaand
11:51:09 RDO-1	One niner zero and then descend and maint sin sin thouaxod
11:51:18 N1566R	LA Center uh Grumman one fhe six six romeo
11:51:23 LA APP	Grumman one five air • ix romeo, this is Loo Angeles Approach

INTRA-COCKPIT

TIME & SOURCE	CONTENT
11:51:30 CM-1	Thank you

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
11:51:26 N1 5661	Uh LA Approach eix six romeo is on a VFR flight out of Fullerton uh vith a first atop uh into Van Nuys VOR deat inat ion gonna be uh Monterey, alt it ude will be four thousand five hundred, ve'd like folloving
11:51:44 LA APP	Aerwexico four ninety eight, maintain your present speed
11:51:48 RDO-1	Roger Aeromexico four ninety eight uh what speed do you vant , ve ' re reducing to tvo niner to one niner zero
11:51:57 LA APP	Okay, you can hold what you have sir, and ve have a change in plans here, stand by
11:52:00 RDO-1	All right we'll maintain one nine --- nine aero
11:52:04 LA APP	Crumman six six romeo aquavk four five two four remain clear of the uh TCA

INTRA-COCKPIT

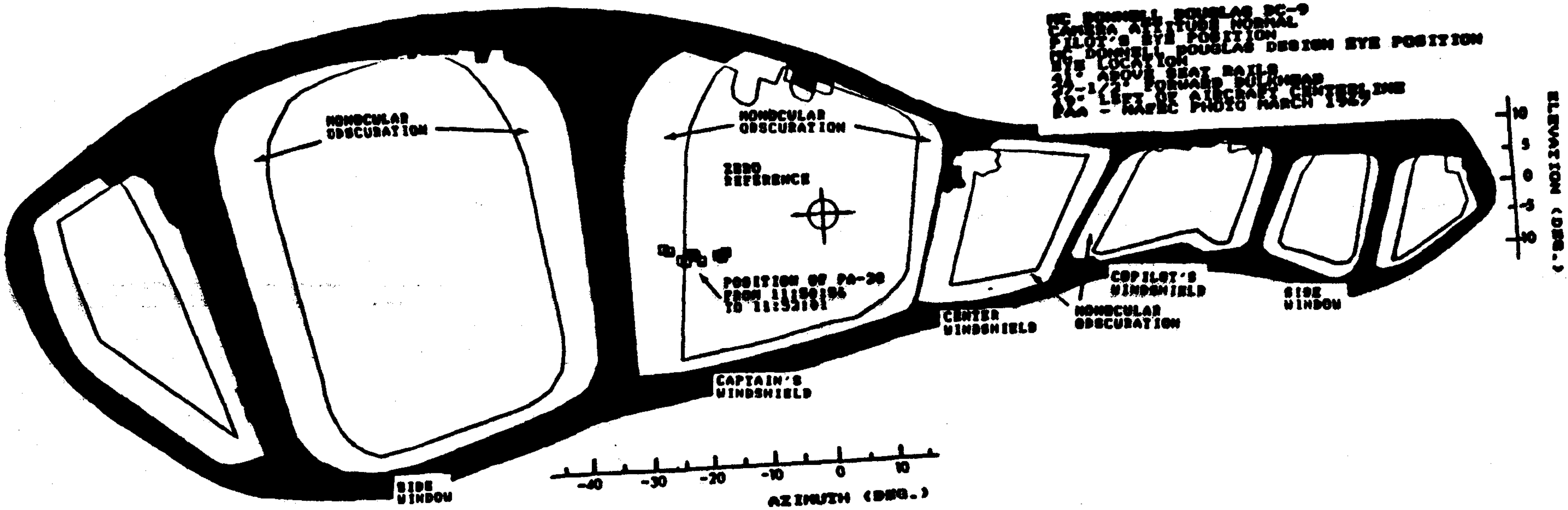
TIME & SOURCE	CONTENT
11:52:10 CAM-1	Oh @ this can't be
11:52:32	((End of Tape))

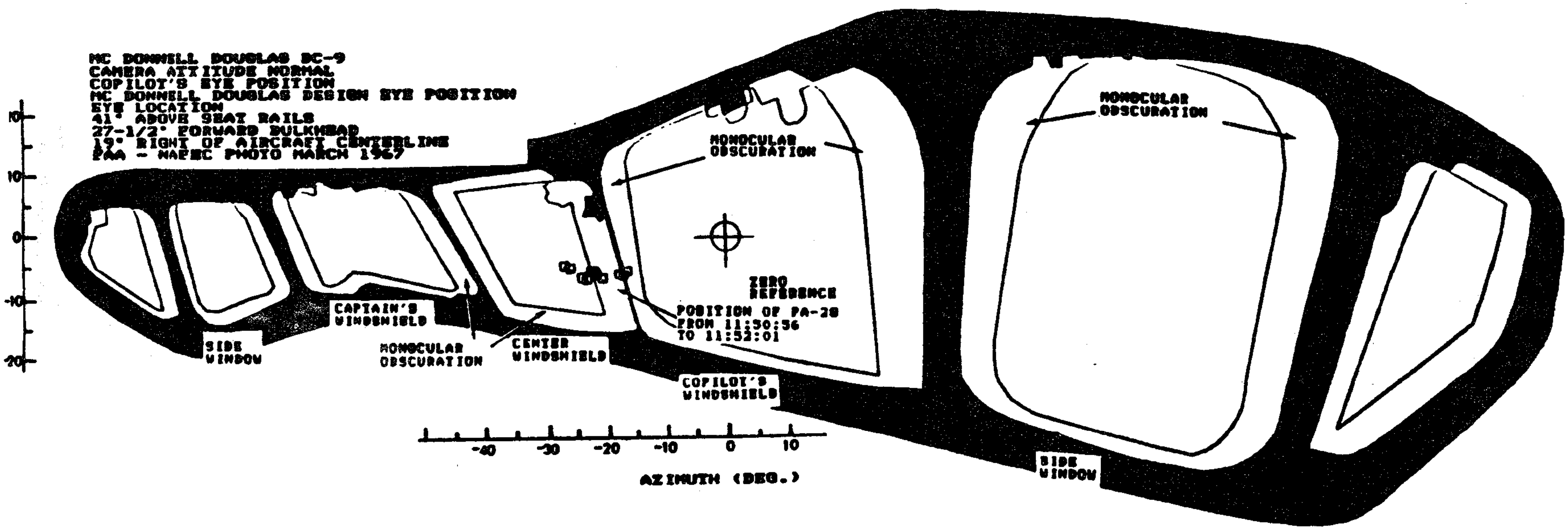
AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
11:52:09 N1566R	Four five, vbat vere the other two numbers
11:52:11 LA APP	Four five tvo four
11:52:15 N1566R	Four five tvo four
11:52:18 LA APP	Aeromexico four ninety eight, expect the ILS runvay two four right approach localizer frequency is one zero eight point five

APPENDIX E
COCKPIT VISIBILITY STUDIES

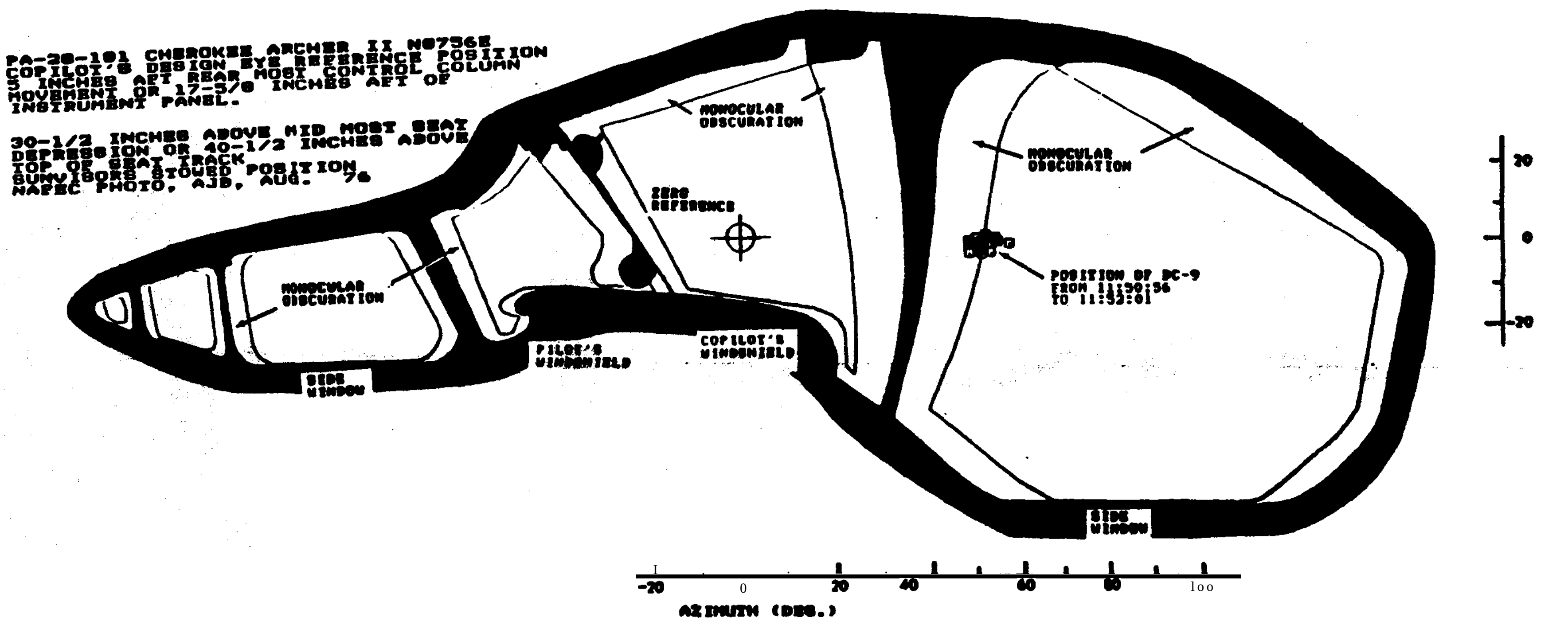
The visibility diagrams for the DC-930, XA-JED, are on pages 72 and 73; those for the Piper PA-28-181, N4891F, are on pages 74 and 75.

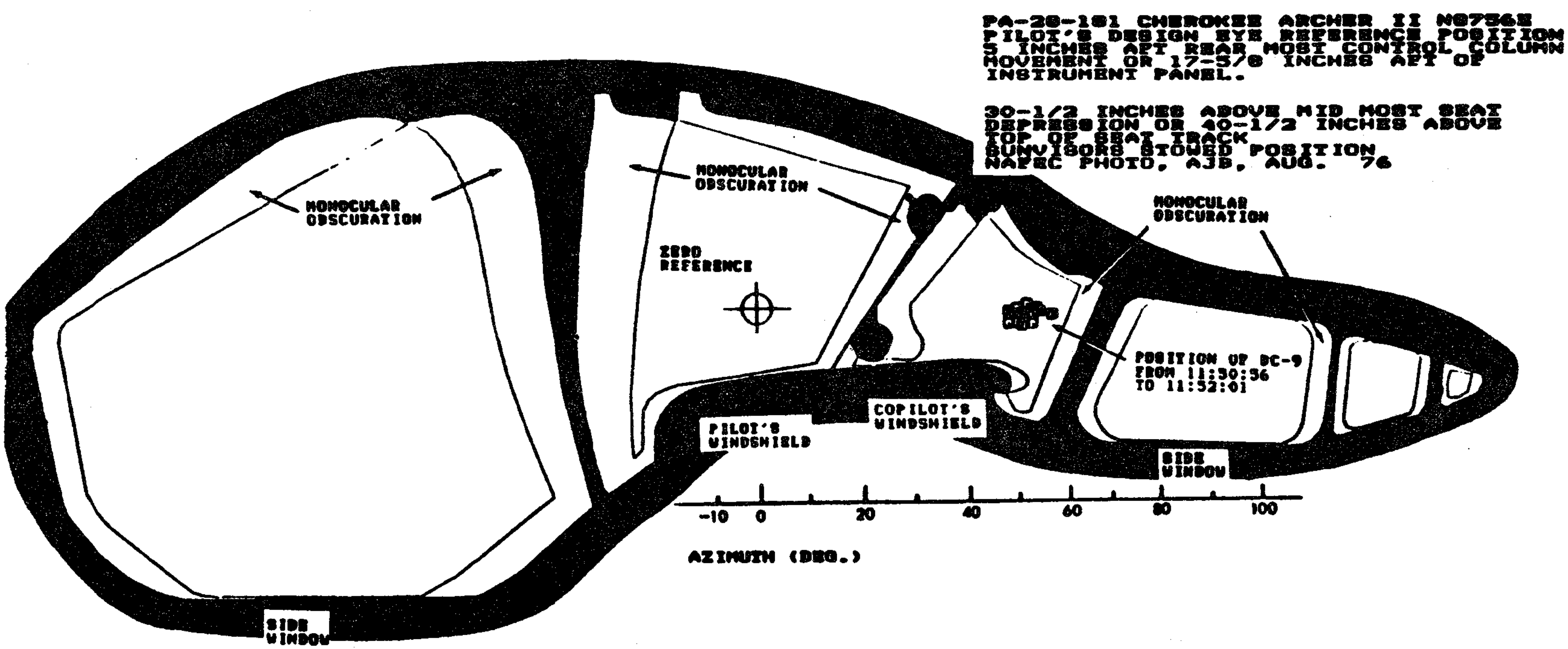

MC DONNELL DOUGLAS DC-9
CAMERA ATTITUDE NORMAL
PILOT'S EYE POSITION
MC DONNELL DOUGLAS DESIGN EYE POSITION
EYE LOCATION
41" ABOVE SEAT RAILS
FAA - NAFEC PHOTO MARCH 1967
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
ZERO REFERENCE
POSITION OF PA-28
CAPTAIN'S WINDSHIELD
CENTER WINDSHIELD
MONOCULAR OBSCURATION
COPILOT'S WINDSHIELD
SIDE WINDOW
SIDE WINDOW
-40 -30 -20 -10 0 10
AZIMUTH (DEG.)
10 5 0 -5 -10
ELEVATION (DEG.)



MC DONNELL DOUGLAS DC-9
CAMERA ATTITUDE NORMAL
COPILOT'S EYE POSITION
MC DONNELL DOUGLAS DESIGN EYE POSITION
EYE LOCATION
41" ABOVE SEAT RAILS
27-1/2" FORWARD BULKHEAD
19" RIGHT OF AIRCRAFT CENTERLINE
FAA - NAFEC PHOTO MARCH 1967
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
ZERO REFERENCE
POSITION OF PA-28 FROM 11:50:56 TO 11:52:01
SIDE WINDOW
CAPTAIN'S WINDSHIELD
MONOCULAR OBSCURATION
CENTER WINDSHIELD
COPILOT'S WINDSHIELD
SIDE WINDOW
10
10
0
-10
-20
-40
-30
-20
-10
0
10
AZIMUTH (DEG.)

APPENDIX E


PA-28-181 CHEROKEE ARCHER II N8756E
COPILOT'S DESIGN EYE REFERENCE POSITION
5 INCHES AFT REAR MOST CONTROL COLUMN
MOVEMENT OR 17-5/8 INCHES AFT OF
INSTRUMENT PANEL.
30-1/2 INCHES ABOVE MID MOST SEAT
DEPRESSION OR 40-1/2 INCHES ABOVE
TOP OF SEAT TRACK
SUNVISORS STOWED POSITION
NAFEC PHOTO, AJD, AUG. 76
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
ZERO REFERENCE
POSITION OF DC-9 FROM 11:50:56 TO 11:52:01
SIDE WINDOW
PILOT'S WINDSHIELD
COPILOT'S WINDSHIELD
SIDE WINDOW
-20
0
20
40
60
80
100
AZIMUTH (DEG.)
20
0
-20
ELEVATION (DEG.)


PA-28-181 CHEROKEE ARCHER II N8756E
PILOT'S DESIGN EYE REFERENCE POSITION
5 INCHES AFT REAR MOST CONTROL COLUMN
MOVEMENT OR 17-5/8 INCHES AFT OF
INSTRUMENT PANEL.
30-1/2 INCHES ABOVE MID MOST SEAT
DEPRESSION OR 40-1/2 INCHES ABOVE
TOP OF SEAT TRACK
SUNVISORS STOWED POSITION
NAFEC PHOTO, AJB, AUG. 76
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
MONOCULAR OBSCURATION
ZERO REFERENCE
POSITION OF DC-9 FROM 11:50:56 TO 11:52:01
PILOT'S WINDSHIELD
COPILOT'S WINDSHIELD
SIDE WINDOW
SIDE WINDOW
-10
0
20
40
60
80
100
AZIMUTH (DEG.)

APPENDIX F
ATC TRANSCRIPT

U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject: INFORMATION: Transcription concerning the accident involving Aeromexico Flight 498 and N4891F on August 31, 1986 at approximately 1852 UTC

Date: September 9, 1986

From: Plans and Procedures Specialist, Los Angeles TRACON

Reply to Attn of:

To:

This transcription covers the time period from August 31, 1986, 1837 UTC to August 31, 1986, 1901 UTC.

Agencies Making Transmissions	Abbreviation	
Los Angeles Terminal Radar Approach Control Arrival Radar 1	AR-1	124,9
Los Angeles ARTCC Sector 20	ZLA 20	
Pacific Southwest Airlines Flight 1765	PS1765	
Wings West Airlines Flight 5225	WWM5225	
Sky West Airlines Flight 222	SKW222	
Wings West Airlines Flight 5083	WWM5083	
Aeranexico Flight 498	AM498	
Grumman AA5, N1566R	N1566R	
American Airlines Flight 333	AA333	

I hereby certify that the following is a true transcription of the recorded conversations pertaining to the subject aircraft accident:

Sham L. Moore

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(1837)

(1838)

(1839)

(1840)

(1841)

(1842)

1842: 14	PS1765	where's the little guy now
1842: 16	AR-1	p s a seventeen sixty five twelve 'clock 'one mile southbound altitude unknown additional traffic twelve o'clock and four miles southeastbound nine thousand three hundred
1842:25	PS1765	looking
1842:55	WWM5225	los angeles approach wings west fifty two twenty five seven thousand uniform

(1843)

1843:Ø5	AR-1	calling 1 a approach say again
1843:Ø8	WWM5225	wings west fifty two twenty five seven thousand uniform

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1843: 12	AR-1	wings fifty two twenty five los angeles approach depart seal beach heading three two zero expect a visual approach runway two five left report airport in sight thanks for uniform
1843: 19	WWM5225	fifty two twenty five we'll do it
1843: 22	AR-l	p s a seventeen sixty five v f r traffic is no longer a factor you have a nice weekend
1843:27	PS1765	thank you sir bye bye
(1844)		
(1845)		
1845:10	AR-1	sky west two twenty two
1845: 14	AR-1	twenty downe ship sky west two twenty two again please
1845: 28	ZLA 20	here he canes
1845: 30	AR-1	thanks
1845: 4C	SKW222	los angeles approach sky west triple two with you we're descending out of niner thousand with the restrictions at fuelr we have the airport uniform
1845:47	AR-1	sky west two twenty two los angeles approach after fuelr cleared for visual approach runway two five right you're number one maintain two hundred forty knots or faster until downe traffic inbound over seal beach is another merlin will have you in sight and follow he's gonna be for two five left

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(1846)

1846:01	SKW222	okay after fuelr we're . cleared for the visual we'll do it at two hundred forty eight to the gate
1846:11	AR-1	wings west fifty two twenty five traffic one o'clock three miles southbound nine thousand three hundred unverified three miles eastbound altitude unknown you're following a merlin inbound from the east straight in for two five right you can expect to see and follow him for two five left
$846: 25	WWM5225	wings fifty two twenty five looking
1846: 40	AR-1	wings west fifty two twenty five reduce Speed to two zero zero then descend and maintain six thousand
1846: 45	WWM5225	reduce to two zero zero then down to six thousand wings fifty two twenty five

(1847)

1847:10	WWM5083	1 a approach wings fifty eighty three with you with uniform with the restrictions
1847:15	AR-1	wings west fifty eighty three los angeles approach after fuelr cleared for i 1 s runway two five left approach sidestep runway two five right
1847:21	WWM5083	after fuelr cleared for the i 1 s two five left sidestep to the right wings fifty eighty three

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1847: 28	AM498	los angeles approach good morning this is aeranexico four sixty four four ninety eight uh we're leaving we're level one correction seven thousand
1847: 40	AR-1	aeranexico four ninety eight los angeles approach depart seal beach three two zero vector i 1 s two. five left final approach course do you have information uniform
1847: 46	AM498	affirmative two five left runway
1847: 53	AR-1	sky west two twenty two traffic twelve o'clock four miles northbound altitude unknown
1847: 57	SKW222	looking triple two
1847: 59	AR-1	wings west fifty two twenty five reduce speed to one seven zero
(1848)		
1848: 03	WWM5225	fifty two twenty five reducing to one seventy we *have* the airport in sight
1848: 06	AR-1	thank you
1848: 22	SKW222	and uh approach was that fifteen hundred *feet* until advised landing for sky west triple two
1848: 27	AR-1	sky west two twenty two correct
1846: 29	SKW222	thank you

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1848: 52	AR-1	wings west fifty two twenty five descend and maintain four *thousand*
1848: 57	WWM5225	four thousand wings fifty two twenty five
1849: 00	AR-1	sky west two twenty two traffic ten o'clock two miles northwestbound is a merlin at six thousand descending he's for two five left
1849: 08	SKW 222	we're looking for him triple two
1849:10	AR-1	say #at again sir
1849:11	SW222	we're looking for him he's not in sight yet
1849: 18	AR-1	wings west fifty two twenty five the merlin you're following is two o'clock and a mile and a half westbound at three thousand expect a turn to final in a mile
1849: 27	WWM5225	fifty two twenty five looking fcr him we still have the airport in sight
1849: 31	AR-1	yes sir i'm gonna need you to see him he's gonna pull out fran under your *nose* in another mile or so
1849:36	WWM5225	roger
1849:37	AR-1	wings fifty two twenty five turn left heading two five zero
1849:41	AR-1	fifty , two twenty five turn left heading two five zero

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1849: 44	WWM5225	left two five zero fifty two twenty five
1849: 46	AR-1	wings west fifty two twenty five do you see the traffic now at your twelve o'clock and a half mile westbound two thousand descend and maintain three thousand
1849:54	WHY5225	down to three thousand wings fifty two twenty five no we don't got him
1849: 57	AR-1	sky west two twenty two contact los angeles tower one two zero point niner five at limma good day

(1850)

1850:01	SKW222	bye bye
1850:05	AR-1	aeranexico four ninety eight reduce speed to two one zero
1850:08	As1490	two one zero four ninety eight
1850: 10	AR-1	wings fifty two twenty five the traffic is now correction turn left heading two three zero the traffic's at eleven o'clock and a mile
1850:18	WWM5225	two three zero fifty two twenty five roger and uh
1850: 22	AR-1	understand you have him in sight
1850:23	WWM5225	yes sir we got him in sight

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1050: 24	AR-1	wings west fifty two twenty'five follow that aircraft he's for two five right you're cleared for a visual approach to runway two five left contact los angeles tower one two zero pint niner five good day
1850: 30	WWM5225	good day
1850:39	AR-1	wings west fifty eighty three traffic twelve o'clock four miles northbound altitude unknown
1850:43	WWM5083	(unintelligible) fifty eighty three
1850:46	AR-1	aeromexico four ninety eight traffic ten o'clock one mile northbound altitude unknown
1850: 50	AM498	roger four ninety eight
(1851)		
1851:04	AR-1	aeranexico four ninety eight reduce speed to one niner zero then descend and maintain six thousand
1851:07	AM498	one niner zero and then descend and maintain six thousand
1851:18	N1566R	1 a center uh grumman one five six six romeo
1851:23	AR-1	grumman one five six six raneo this is los angeles approach
1851:26	N1566R	uh 1 a approach six six romeo is on a v f r flight out of fullerton uh with a first stop uh into van nuys v o r destination gonna be uh monterey altitude will be four thousand five hundred we'd like following

LAX-TRACON-068
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1851: 45	AR-1	aeranexico four ninety eight maintain your present speed
1851:48	AM498	roger aeranexico four ninety eight uh what speed do you want we're reducing to two niner to one niner zero
1851:57	AR-1	ok you can hold what you have sir and we have a change in plans sir stand by
1852: 00	AM498	alright we'll maintain one niner zero
1852: 04	AR-1	grumman six six romeo squawk four five two four remain clear of the uh t c a
1852: 09	N1566R	four five what were the other two numbers
1852:11	AR-1	four five two four
1852: 15	N1566R	four five two four
1852: 18	AR-1	aeranexico four ninety eight expect the i 1 s runway two four right approach localizer frequency is one zero eight point five
1852: 29	AR-1	grumman six six romeo are you at four thousand five hundred now
1852: 32	N1566R	uh negative we're at three thousand four hundred climbing
1852: 36	AR-1	ok you're right in the middle of the t c a sir grumman six six raneo i would suggest in the future you look at your t c a chart you just had an aircraft pass right off your left above you at five thousand and we run a lot of jets through there right at thirty five hundred

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1852: 50	N1566R	i was with coast approach and they did not advise me of this i was with Ontario approach and they sent me over to you what do you suggest i do now
1852: 58	AR-1	aeromexico four ninety eight turn left beading two eight zero
(1853)		
1853:03	AR-1	aeranexico four ninety eight turn left heading two eight zero
1853: 08	AR-1	aemnexico four ninety eight turn left heading two eight zero
1053: 15	AR-1	grumman six six romeo standby aeranexico four ninety eight turn left heading two eight zero over
1853: 24	AR-l	aeranexico four ninety eight los angeles approach
1853: 31	Ah333	los angeles approach american three thirty three heavy one zero thouand for the two five profile descent and uh we have uh uniform
1853:43	AR-1	aeromexico four ninety eight los angeles approach
1853:48	AR-1	wings fifty eighty three tower one two zero point niner five
1853:58	AR-1	aeranexico four ninety eight los angeles approach

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(1854)

1854:08	AA333	los angeles approach. american three thirty three heavy uh descending but of nine point four for the profile descent and uh we have uniform
1854:22	AR-1	aeromexico four ninety eight los angeles approach
1854: 28	AR-1	american thr three thirty three heavy maintain eight thousand
1854:31	AA333	american three thirty three maintain eight thousand
1854:57	AR-?	grumman six six romeo you're leaving the los angeles t c a now radar service is terminated squawk one two zero zero frequency change is approved good day

(1855)

1855:16	AR-1	aeranexico four ninety eight los angeles approach
1855:28	AR-1	american three thirty three heavy uh standby
1856:01	AA333	we need lower american triple three heavy
1856:05	AR-1	american three thirty three heavy negative uh i want you to look around at eleven o'clock and about five miles i just lost contact with a d c nine let me know if you see anything down there please
1856:17	AA333	uh eleven o'clock uh five miles what altitude

LAX-TRACON-068
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1856: 21	AR-1	he was last assigned six **he's no longer on my** radar scope **american** three thirty three heavy
1856: 26	AA333	okay i see a uh very large uh **smoke** screen **off** on the left side of the aircraft **abeam uh** the **uh** the nose of the airplane right off our left it is a very large **smoke** uh **column** uh caning **from** it and uh **emanating** *fran* the ground and at our altitude at eight thousand feet there's another **smoke column** vertically overhead it looks like it **something smoked** up uh ahead **and** then went down in

(1857)

(1858)

(1859)

(1900)

(1901)

END OF TRANSCRIPT

APPENDIX G
FAA RECOMMENDATIONS

U.S. Department of Transportation

Federal Aviation Administration

Memorandum

Subject: ACTION: Agenoy Aotion to Implement Reoommendations Developed by the Terminal Control Area (TCA) Task Group

Date: October 30, 1086

From: Administrator

Reply to Attn. of:

To: Associate Administtrtot for Aviation Standards
Associate Administtrtot for Air Traffio
Chief Counsel
Direotor of Aviation Ssftty
Assistant Admlnlsttstot of Publio Affairs
Diteotot, Attonautiosl Center

In September I direoted that 8 TCA Review Task Group examine the size, shape, traffio oount, ooapltxity, number, type of flight infraotions, past • nfototmtnt efforts, and any other factors whloh would allow the FAA to improve traffio flow and srft separation within and around TCA's. The Task Group was asked to provide me with reoommendations whloh would enhanoe the tfftotiveness of the TCA oonoept. On Ootober 15 the Task Group submitted an extensive list of reoommendations involving TCA design, ATC ptootdutts, enforoement, and pilot • duostion.

After reviewing the proposed reoommendations, I have determined that the following require aotion:

1. Adopt standardized prooedures for traoking TCA intruder airoraft to Inolude handoff between adjaoent ATC faoilities 8nd 8eotots. (AAT)

2. Investigate the potential for improvement in the terminal and en route automation system tracking oapability to tag primary and oode 1200 beaoon targets. (AAT)

3. Examine the potential for inoluding • utomstlo deteoting -monitoring and ttsoking of intruding airoraft in rdvsnotd automation specifioations. (AAT)

4. Utilize the capability of Mode S equipment to assign a discrete transponder code to each Node S equipped aircraft to identify aircraft which are not complying with FAR 91.90. (AAT)

5. Reduce the processing time for changes in alroraft and pilot registration records. (AAC)

6. Consider increased penalties for providing FAA false information pertaining to aircraft registration and pilot certificate information. (AGC)

7. Establish a procedure for notifying the reporting controller of the final outcome of an enforcement action for a TCA violation reported by the controller. (AGC/AAT)

8. Examine the established procedures for initial and followup submission of Incident Report (FAA Form 8020-5) and other information from the air traffic facility to the flight standards office, and provide recommendations a8 to how to avoid routine submission of full documentation before it is necessary. In addition, evaluate the possibility of having two ATC facility personnel certify the copy of voice tapes to be used in enforcement rations in order: to ensure that at least one employee will be available for enforcement hearings. (AGC/AAT)

9. Examine the potent181 for automatic plotting • nU extraotlon of ARTS XII data if such data are neoessary for TCA enforcement actions. (AAT)

10. Ensure that en Inoldent Report is filed on all TCA-related pilot deviations and that Safety Improvement Report8 are filed only when warranted. (AAT)

11. Suspension orders for TCA violations should require that the pilot pass an FAA written test on controlled • lasproe and procedures before the suspension is lifted. The suspension would not be less than 60 days and would oontlnue until the pilot passes the written test. (AGC/AVS)

12. In oases where the lnspeotor determines that there 18 a question as to the pilot's competency at navigation, the suspension should require a Section 609 Requalification Check for navigation oompetenoy in addition to the 60-day suspension and written test requirement. (AGC/AVS).

13. Require suspension of piloting privileges for more than 60 days for any TCA violation which results in a Near Midair Collision (NMAC) report classified as "critical" or "potential hazard." (AGC/AVS/AAT)

14\. **Initiate a** ● tudy to determine ♦♒♏ ● **ffeotlvwmar** of **the enforoement** polloy **on penalties for TCA violations. The target** dote **for oompletion of the study is September** *30,* **1987. (ASF)**

15\. **Issue monthly press releases** on ♦♒♏ ● *nfosoment* ● 888ure8 **and types** Of **sanotions** ● dQini8trred **to TCA violators when the** *number* Of ● ⚐♦♓⚐■✓ **warrants a pressrelease. (APA/AGC)**

16\. **Simplify** ● **nd standardize TCA design as muoh as practioable.** **Develop** *new* **TCA design oriteria and oiroulate for public/industry oomments. Consider the following as potential oriteria:**

a. **Tops of all TCA's** ● **t 10,000** ♐♏♏♦ **MSL or 7,000 feet AGL, whiohever 18 higher. (AAT)**

b\. **Lateral limits 30 miles from the primary airport. (AAT)**

c\. **Inner? surfaoe area of TCA's a maximum** of *10* **miles from** the **primary airport, oonsistent with runway alignment. (AAT)**

d\. *300* foot **per nautioal mile gradient from the inner area out to** *20* **miles. (AAT)**

e\. **Area** *between* **20** and *30* **miles should be oonsistent with** ● **pproroh/d8p8rtune prooedures. (AAT)**

17\. *Expedite* **rulemaking to** ● **8trbllrh one** type of *TCA* ***in*** **line with WAR** ● **ttabll8hment oriteria and amend FAR 91.90** ● **oootdingly. (AAT)**

18\. **Issue appropriate rulemaking notioes proposing the** following new **requirements:**

0. **Require** *on* **operating Mode** *C* **transponder** *in* **all** ● Irspooe **from the surfaoe** to **12,500** feet **MSL** within *30* **miles** of **the primary TCA a irport. (AAT/AGC/AVS)**

b\. **Extend the fixed-wing a iroraft equipment requirements to helioopters** *operating* **in TCA's. (AAT/AGC/AVS)**

c\. **Extend the equipment requirements oontained** *in* **FAR 91.90(a)** *to* **all airoraft operating within all TCA's. (AAT/AGC/AVS)**

d\. **Initiate rulemaking** *to* **propose requiring** the pilot **in oommand** of **a oivil airoraft operating within a** TCA **to bold a** *private* pilot **oertifioate or higher. (AVS/AGC)**

19. Evaluate eooh existing TCA to determine if the traffic oonditions warrant restriotion oP. prohibition of VFR transit through the area. · Provide specific ATC controlled VFR transit routes through those TCA's able to ● ooommod8te that ● otlvlty safely. (AAT)

20. Examine the feasibility of installing a VORTAC (VOR/DME) on each TCA primary airport. I f feasible, utilize VOR/DME and crossing radial definition for TCA boundaries. (AAT/ASF)

21. Develop baseline data and analysis methods for evaluation of TCA's to lnoludt user attitudes, knowledge of TCA's, NMAC data, pilot dtvlotlon dote, and operations ● PPOP dote (post 1985). Determine the number and type of intrusions into specific TCA's. (ASF)

22. Take action t o simplify and standardize charting which defines TCA boundaries. (AAT)

23. Develop advisory oiroular material t h a t identifies topics to be aoyertd by Certified Flight Instructors (CFI) and others when administering Biennial Flight Reviews (BFR). The use of TCA an d other controlled airspace shall be a topic. (AVS)

24. Initiate 0 regulatory requirement fat CFI's to report the completion of 011 BFR to the FAA. The purpose of the report would be to affirm that a pilot has passed the BFR and has demonstrated satisfactory knowledge of the topic areas identified in advisory ciroulars pnopostd in Recommendation 24 above. (AVS)

25. Establlrh notlonrfly standardized ptooedurts which would' encourage participation O f air traffic control specialists familiar with TCA operations in pilot training seminars. (AAT)

26. Examine and determine the feasibility o f using "gateway" VOR advisory services to provide TCA airspace information tot pilots approaching TCA boundaries. (AAT)

27. Examine and determine the feasibility of utilizing 0 channel associated with Pilot Automatic Telephone Weather Answering Service (PATWAS), for providing pilots with specific TCA location information through automrttd flight service stations. (AAT)

28. Examine the potential benefit Of increasing the passing score on airmem written tests to a grade higher than 70 percent. (AAC)

29. Revise, update, and reprint for distribution, Air Carrier Operations Bulletin #8-78-3 ("Importance of Cockpit Crew Members External Vigilance"). (AVS)

30. Examine 011 ● xi8tlng,lnformrtion ● vollobl t to the airmen regarding TCA concept, design, procedures, etc., and determine if that lnformotlon is adequate. Update both the content and methods Of distribution where necessary. (AVS/AAT)

31. Develop a standardized refresher training program for Air Traffic and Flight Standards personnel which highlights their respective responsibilities to the aviation community regarding VFR operations in and around TCA's. (AVS/AAT)

32. Evaluate the feasibility of utilizing terminal ● nhonotd target *generator* training programs to improve the control and ooordlnotlon of VFR *pop-up* trofflo requesting TCA service. (AAT)

33. Take steps *ntatssory* to ● n8uPt that 011 air traffic facilities provide the required TCA training to pertinent personnel. (AAT)

34. Take steps necessary to ensure that the Oklahoma City Designated Examiner (DE) team provides updated information to DE's and tests DE's knowledge of TCA's and other oontrolltd ● lPspoot. (AVS)

35. Take 8ttps necessary to ensure that Designated Examiners test 011 ● lrm8n ● ppllo8nts on their knowledge of TCA's and other oontrolltd ● lrspoot. (AVS)

36. Ensure that *811* CFI's are similiar with TCA's and other oontrolltd ● iP8pOOt prior to biennial recertification. Provide CFI's with methods for: *use* in training their students *about* TCA's. (AVS)

37. Develop a "Back-to-Basics" presentation which teoohts what a TCA *18,* how to ● ... it, and how to use it. (ASF/AVS)

38. Encourage *the* ● vlotlon industry to require special TCA airspace checkout for pilots based within 0 prescribed distance from TCA primary ● :l?pOPtS. (AVS/AAT)

39. Evaluate the extent of additional resources necessary to accomplish the following:

a. Use of dedicated personnel to monitor radar for TCA violators. (AAT)

b. Establishment of position descriptions ● uoh as "assistants" OF "technicians" to help handle invesitgations and vlolotlon case preparation at FSDO's. (AVS)

o. Inoreased staffing a t air traffio facilities, Flight Standards Distriot Offioes, and Rtglonol Counsel offioes, as neoessary, to handle inoreases in enforoement oases d u e to emphasis On TCA violators. (AAT/AVS/AGC)

d. Establishment o f an expanded radar servioe (ERS) position at eaoh TCA looation. It is oonttmplottd that this position would funotion OS follows: All VFR airoraft requesting entry into the TCA would be required to oontrot this oontroller for idtntlflootlon and to *state* intentions. The ERS oontroller would oonstantly evaluate *trrfflo* oondltlons and deny *or* approve entry into the TCA. The airoraft would then be handed *off* to the appropriate rector oontrolltr. This ERS oontroller oould 0180 monitor, traok, and rtoord TCA intrusions. The duties of this ERS position would be similar to the duties of • porltlon now in use In the Wew York TRACON. (AAT)

Esoh offioe responsible *for* the disposition of one or more of these reoommendations shall report its intended aotions and milestones to me *no* later than November 15. As AAT has *the* lion's share *of* the aotions, I hive asked that offioe to *trook* this overall effort and to keep me • bPt8St of the progress made toward intended milestones.

Donald D. Engen

STATUS OF FAA RECOMMENDATIONS

According to the FAA, as of May 14, 1987, action has been completed on recommendations 2, 3, 4, 5, 9, 10-13, 15, 19, 29, 28, 29, and 31-39. Although recommendations 2, 3, and 9 were classified as completed, the actions contained therein will not be implemented until the Advanced Automation Systems (AAS) are placed in the TRACONS. According to the National Air Space (NAS) plan, installation of the AASs is scheduled to begin in 1994 and to be completed in 1997.

Recommendation 4 requires mode S transponders for compliance. The first operational mode S is scheduled for March 1, 1990. The projected date for full mode S coverage in the continental U.S. is January 1, 1997.

Recommendations 17 and 18 require rule action for completion. The required Notices of Public Rule Making were issued on June 6, 1987, and publication of the final rules in the Federal Register is scheduled for November 1, 1987.

Except for recommendations 21 and 24, action on the remaining recommendations is scheduled to be completed by December 31, 1987.

Action on recommendation 24 requires the initiation of a regulation. Action on this proposal has been made a part of the Office of Flight Standards regulations review of 14 CFR Parts 61, 141, and 143. This recommendation will be considered during this rulemaking project; however, milestone dates for the project have not been established.

APPENDIX H

MID-AIR AND NEAR MID-AIR
SAFETY BOARD RECOMMENDATION HISTORY

Since 1967 the Safety Board has issued 116 recommendations as a result of investigations of mid-air or near mid-air collisions and special studies/investigations of mid-air accidents. Due to the sheer number of recommendations on this subject, the recommendation data base was initially reduced to include only cases involving air carrier aircraft. The unselected recommendations were then reviewed to determine whether they addressed issues that were appropriate to the accident at Cerritos, California. Accidents in this group involved mid-air collisions or near mid-air collisions between general aviation aircraft and military aircraft, general aviation aircraft and corporate aircraft, general aviation aircraft and air taxi/commuter aircraft, and only general aviation aircraft. Additionally, recommendations that resulted from accidents involving air carrier aircraft but which addressed unique or site-specific issues were not included in the data base for this appendix. This review resulted in identifying 56 recommendations from 17 accidents over a 19-year period that are pertinent to the accident at Cerritos. These recommendations are as follows:

As a result of its investigation of an accident of a mid-air collision involving a Trans World Airlines DC-9 and a Beechcraft Baron near Urbana, Ohio, on March 9, 1967, the Safety board issued the following recommendation to the Federal Aviation Administration (FAA):

A-67-25

> Survey the types of general aviation airplanes equipped with solid type visors to determine the extent of the resultant vision impairment; where it is found that they severely hinder the pilot's vision, the solid visor should be replaced by a see-through type; additionally, we recommend that, if this survey shows the solid type visors adversely affect the visibility from the aircraft, Part 23 be amended to provide that when a sun visor is installed on future airplanes, it be a see-through type if it can be positioned so that it extends into the area of vision necessary for collision avoidance.

On November 9, 1967, the FAA informed the Board that. it planned to survey the types of general aviation fleet equipped with sunvisors to determine the extent of the resultant vision impairment. Based upon this survey, the FAA issued airworthiness directives where applicable and an advisory circular cautioning pilots on the judicious use of sunvisors. The Board found the FAA's action to comply with the intent of the recommendatbn and it was classified as "Closed--Acceptable Action."

Following the Board's investigation of a mid-air collision at St. Louis, Missouri, on March 27, 1966, between an Ozark Airlines DC-9 and a Cessna 150, the following recommendation was issued to the FAA:

A-68-12

A. That daylight radar display equipment be installed in the Lamber field tower cab at the earliest possible date.
B. That greater utilization of the facility radar, be made so as to provide radar sequencing, monitoring, and advisory service on a full time basis until phase II of the national terminal radar service program can be implemented at St. Louis.
C. That VFR patterns (entry points, tracks, and altitudes) be established for the Lambert Field control zone to be utilized by those aircraft not participating in a radar program.
D. That all of the above recommended actions be considered for their applicability to other locations similar to St. Louis. Should you or the members of your staff require additional information on this matter, Board personnel will be available for assistance.

On June 28, 1968, the FAA responded that it had: installed bright tube radar displays at St. Louis, included St. Louis in Stage II of the National Radar Program, established VFR entry and departure routes for Lambert Field, and had identified and was taking action to correct airports that had problems similar to St. Louis's Lambert Field. The Safety Board continued to monitor the FAA's efforts to comply with this recommendation and on January 1, 1985, classified Safety Recommendation A-68-12 as "Closed--Acceptable Action."

On July 19, 1967, a Piedmont Airlines 727 and a Cessna 310 were involved in a mid-air collision near Hendersonville, North Carolina. Following completion of its investigation, the Safety Board issued the following recommendation to the FAA on September 20, 1968:

A-68-26

1. lmprove ATC communication methods and procedures for IFR in nonradar environment.

2. Expedite increases in ATC radar coverage.

3. Establii more stringent requirements for pilots using IFR system.

4. Require an annual proficiency flight check for all IFR pilots.

In response to the first two parts of this recommendation the FM said that it would make improvements to the ACT system and expand radar facilities as budgetary limits provided. On March 18, 1971, the FAA informed the Board that it had started rulemaking action that would require experience and qualification requirements for pilots serving as second in command and annual proficiency checks for pilots in command for aircraft certificated for more than one pilot. The Safety Board found this action to be acceptable and on May 7, 1971, this recommendation was classified as "Closed--Acceptable Action."

Following a mid-air collision at Shelbyville, Indiana; on September 9, 1969, the Safety Board issued the following recommendation to the FAA:

A-69-18

1. Undertake an educational program to make both pilots and controllers more aware of the midair collision problem, and to make pilots aware that most collisions occur at or near airports in clear weather and in daylight hours.

2. Establish a continuing program to assure indoctrination and continuing awareness on the part of all pilots to the midair collision potential and avoidance techniques (i.e., "see and be seen" concept, descent, turn, and climb maneuvering techniques, etc.).

3. Examine more stringently all pilot applicants for their external cockpit vigilance, with particular attention to pilots who are tested for flight instructor ratings.

4. Provide special warning and guidance to pilots who are required by the nature of their operations to fly in pairs.

5. inform all certificated flight instructors of the high statistical significance of their involvement in midair collisions.

6. Encourage all instructor pilots to notify the control tower operator, at airports where a tower is manned, regarding first solo flights, and require the tower operator to advise other traffic in the pattern about such flights.

7. Conduct detailed traffic flow studies for all high-volume general aviation controlled airports with a view to improving the VFR traffic flow techniques of the ATC personnel.

8. Designate climb and descent corridors for high performance aircraft at high-density airports.

9. Irrespective of the provisions contained in Part 91 of the Federal Aviation Regulations, establish standard entry, departure, and go-around procedures for each uncontrolled airport.

10. In cooperation with Environmental Science Services Administration (ESSA), develop and produce VFR approach and departure charts for selected airports with a high volume of traffic.

11. In addition to the requirements of Section 91.89 of Part 91 of the Federal Aviation Regulations, develop a requirement for the installation of surface pattern indicators (for day and night) at smaller airports which would define specific patterns, particularly the base leg and the final approach.

12. Reevaluate visual oonspicuity standards for all civil aircraft;

13; Consider the establishment of requirements for the installation and day and night operation of high-intensity white flashing lights on all civil aircraft.

14. Support the expeditious development of low-cost Collision Avoidance Systems for all civil aircraft.

On October 23, 1969, the FAA wrote the Roard stating that the subject of mid-air collisions required more attention than could be addressed by this recommendation. The Roard agreed and decided to hold a public hearing to better identify areas where immediate action was needed. Safety Recommendation A-69-18 was subsequently classified as "Closed--Reconsidered."

On November 4, 1969, the Roard convened a public hearing on the subject of the prevention of mid-air collisions. The following recommendations resulted from that hearing and were issued to the FAA on January 30, 1970:

A-70-6

Convene a government/industry meeting to specifically examine the factors involved in establishing the need for standard traffic patterns.

A-70-7

Review the Chicago terminal area notice in Part 3 of the airman's information manual with a view to the expedited development of similar charts for other terminal areas wherever the mix of aircraft warranted.

A-70-8

Require FAR pilots be given ground training scanning patterns to optimize aircraft detection and thus make more productive the pilot time spent when looking outside the cockpit. The Board further recommended that detection training equipment be developed on a priority basis and made available for private pilots also, as their need for such training was as important as that of commercial pilots.

In its letter of February 9, 1970, the FAA. informed the Board that it was in the process of developing and distributing copies of terminal area charts for 22 large airports and selected medium airports where there was a considerable mixture of traffic. Based upon this action, Recommendation A-70-7 was classified as "Closed-Acceptable Action."

On January 21, 1972, the FAA informed the Board that it did not plan to require that pilots be given ground training in visual scanning patterns because training devices for such training were not readily available. However the FAA did plan to work with flight schools in encouraging them to incorporate visual scanning in their programs. The Board upheld its position that the FAA should require such training and subsequently classified Safety Recommendation A-70-08 as "Closed--Unacceptable Action."

In February 1975, the FAA provided the Board with a copy of Advisory Circular 90-66, which recommended standard traffic patterns. The Safety Board found this action to be satisfactory and classified recommendation A-70-6 as "Closed- - Acceptable Action," on October 1, 1975.

On February 22, 1971, the Board issued an additional 11 recommendations to the FAA as a result of the Board's November 4, 1969, public hearing on the cause and prevention of mid-air collisions. These recommendations are as follows:

A-71-5

Evaluate the pilot qualifications and minimum airborne equipment necessary for safe operations into high-density terminal areas with a view toward increasing the minimum standards for each.

A-71-6

Accelerate the program to provide separation between high- and low-performance aircraft in high-density terminal areas.

A-71-7

Encourage the expeditious development of a collision avoidance system for installation in air carrier aircraft and larger general aviation aircraft.

A-71-6

Make funds available for the ground equipment which may be necessary for support of CAS systems.

A-71-9

Sponsor developmental contracts for pilot warning indicator (PWI) systems utilizing various technological methods in order to evaluate the practicality of each.

A-71-1 0

Develop regulations to require the installation of CAS and PWI systems when they become available from the activities of 2 and 5 supra.

A-71-1-1

Consider convening a special Government/Industry meeting for the purpose of discussing the factors involved in establishing standard traffic patterns and initiating action leading to their creation.

A-71-12

Amend the pilot training requirements in the Federal Aviation regulations to require the addition of scanning techniques to the training syllabus.

A-71-1 3

Require suitable training aids be used to augment the syllabus when such aids are developed.

A-71-1 4

Promulgate regulations to require the installation of white anticollision lights on all aircraft as soon as possible.

A-71-1 5

Accelerate its efforts in developing certification, procedural, and rulemaking processes involved in implementing a full area navigation (RNAV) system for utilization throughout the U.S. National Airspace System.

In response to recommendations A-71-5 and -6, the FAA informed the Board that the requirements for group I and II terminal control areas would provide for increased pilot qualifications, airborne equipment, and aircraft separation. The Board agreed with the FAA's actions and these two recommendation were classified as "Closed-Acceptable Action."

In response to recommendations A-71-7, -6, -9, and -10, the FAA informed the Board that it had established an industry/government cooperative program to develop and flight test pilot warning indicators and collision avoidance systems. Funding for these efforts was included in the FAA's lo-year plan. The FAA informed the Board that as the necessary equipment and installation requirements matured, regulations would be developed to require the installation of these systems. Safety Recommendations A-71-7 through -10 were classified as "Closed-Acceptable Action."

With regard to recommendation A-71-11,, the FAA had held several meetings with user groups to discuss establishing standard traffic patterns. The Board found this action to be satisfactory and subsequently this recommendation was classified as "Closed--Acceptable Action."

In response to recommendations A-71-12 and 13, the FAA stated that it had issued a Notice of Proposed Rulemaking on this subject, and that the comments received either opposed the proposed rule or requested that additional research and development be accomplished prior to further action being taken. In its evaluation the Board noted that these recommendations were similar in intent to recommendation A-7- 8 and therefore closed recommendations A-71-1 2 and 13 as "Acceptable Action."

In response to recommendation A-71-14; the FAA issued a new rule requiring the installation of anticollision lights and a minimum intensity level for anticollision lights on new aircraft. Based upon this action, recommendation A-71-14 was classified as "Closed—Acceptable Action."

In its letter of March 25, 1971, the FAA informed the Board that it had revised 14 CFR parts 71 and 75 concerning the designation of area low and area high navigation routes and that approximately 150 routes had been developed. The Safety Board accepted the FAA action as responsive to the intent of recommendation A-70-15 and therefore classified the recommendation as "Closed—Acceptable Action."

Upon completion of its investigation of a mid-air collision near Fairland, Indiana, on September 9, 1969, involving a McDonnell-Douglas DC-9 and a Piper PA-28, the Safety Board issued the following recommendation to the FAA:

A-70-9

> Board had recommended that Parts 21 and 23 of the FAR be modified to require all aircraft under 12,500 lbs., manufactured after some appropriate date, to possess a radar cross section suitable for primary target detection, the Board was now of the view that a more appropriate regulatory approach would be to amend Part 91 of the FAR's to require all aircraft operating in radar service environments to have a minimum level of radar cross section, such action should make it possible for some operators, never intending to operate in radar environments, to avoid the necessity of reflective augmentation.

The FAA response to this recommendation was that effective June 25, 1970 transponders were required on all airplanes operating within group terminal control areas (TCA). While the Board agreed that' the requirement to have transponders was eommendable, it did not satisfy the intent of this recommendation that radar target detection be improved in all radar environments, not just the TCAs. On January 11, 1974, the Board classified this recommendation as "Closed—Unacceptable Action."

As a result of the January 8, 1971, mid-air collision involving an American Airlines Boeing 707 and a Cessna 150, over Edison Township, New Jersey, the Safety Board issued the following recommendations to the FAA:

A-71-58

> The Administrator establish procedures whereby all operators of civil flying training schools will formally advise appropriate Federal Aviation Administration authorities of the locations and dimensions of designated practice areas for student flying training, and that such information be disseminated to all affected services within the FAA.

A-72-104

Assigned altitudes should be maintained as precisely as possible.

A-72-105

Visibility and separation from cloud distances should be assessed conservatively in VFR operations, and that VFR flight should be continued only when visibility is unquestionable.

In response to recommendation A-71-58, the FAA issued order 7410.1, which applied procedures for the establishment of certificated flight school practice areas. Additionally, the FAA notified instructors of this problem through the FAA flight instructor refresher clinics. Safety Recommendation A-71-58 was classified as "Closed-Acceptable Action," on June 4, 1975.

No response was required for recommendations A-72-104 and -105 because these recommendations were intented to be advisory. For bookkeeping purposes only, they were classified as "Closed-Acceptable Action."

Following the Board's investigation of a mid-air collision involving an Eastern Airlines DC-9 and a Cessna 206 at Raleigh-Durham, North Carolina, on December 4, 1971, the Safety Board issued the following two recommendations to the FAA:

A-72-27

Require an exchange of pertinent traffic information between the control tower and the associated radar approach control facility whenever a pilot who is operating in accordance with VFR has requested a service or stated his intended flight operations, Such exchanges of information should be accomplished on a lower priority basis than that accorded to the transmission of control clearances.

A-72-28

Require the pilots of all aircraft equipped with an operable transponder to have the transponder turned "ON" and adjusted to reply on the appropriate mode A/3 code whenever VFR operations are conducted into, or in proximity to, an airport serviced by a radar approach control facility.

On April 12, 1972, the FAA responded that the airman's information manual already contained information on the use of transponders in VFR operations. Additionally, the FAA issued a rule that required the use of a transponder with mode C capability at 21 of the busiest terminal areas, and at 42 additional locations improved transponders would be required. In this same letter, the FAA stated that procedures were instituted that improved the coordination of traffic within an airport traffic area. On December 14, 1973, the FAA informed the Board that 14 CFR Part 91 had been revised with respect to transponder requirements. Recommendations A-72-27 and -28 were classif ied as "Closed—Accept able Action."

A-78-83

Reevaluate its policy with regard to the use of visual separation in other terminal areas.

A-79-73

Prescribe an appropriate method to do so and require all air carrier companies and commercial operators to test their pilots recurrently on ATC radar procedures, radar services, pilot/controller relationships, and ATC clearances.

A-79-74

Prescribe a method to insure that all general aviation pilots are tested periodically on ATC radar procedures, radar services, pilot/controller relationships, and ATC clearances as appropriate to their operations.

In its response to recommendation A-78-77, the FAA informed the Board that it had established a terminal radar service area at Lindbergh Airport and that several improvements had been made to the airport traffic control equipment. Based upon these actions, recommendation A-78-77 was classified as "Closed—Acceptable Action."

In it letter of April 17, 1981, the FAA stated that following its evaluation of traffic at major airports it had established 48 additional TRSAs, bringing the total number to 137 with 26 other locations still under consideration, and that 2 new TCAs were added with another 31 locations still being considered. The Board found these actions to be satisfactory and classified recommendation A-78-78 as *Closed-Acceptable Action."

The FAA disagreed with the Board's recommendations A-78- 82 and -83, stating that it believed that the use of visual separation in TCAs and TRSAs is a viable concept and that complying with the Board's recommendation would have an 'adverse effect on the efficient use of airspace and increase delays in the TRSAs. In its evaluation of August 20, 1896, the Safety Board stated that it did not agree with the FAA's assessment. Recommendations A-78-82 and -83 were classified as "Closed—Unacceptable Action."

In response to recommendation A-79-73, the FAA issued a change to order 8430.17, Air Carrier Operations Bulletin, which outlined procedures to be followed by the POIs to ensure that pilots were tested recurrently on ATC procedures. Safety Recommendation A-79-73 was classified as "Closed-- Acceptable Alternate Action."

In response to recommendation A-79-73, the FAA developed a slide and tape presentation that advises pilot of proper procedures for operating in TCAs and TRSAs. Safety Recommendation A-79-74 was classified "Closed—Acceptable Action," on June 8, 1981.

On May 18, 1978, a Cessna 150 and a Falcon Fan Jet collided in mid-air about 3.5 miles west of Memphis International Airport, Memphis; Tennessee. While this accident did not involve an air carrier, two of the three recommendations which resulted from this accident are pertinent to the accident at Cerritos. These recommendations are:

A-78-80

> Evaluate operational data for each TRSA location and establish two categories of TRSA's. Those locations handling the largest volume of traffic with automated ATC equipment available should be designated TRSA I locations. The remaining areas should be designated TRSA II locations.

A-78-81

> Require Mode "C" transponder equipment for operations within a TRSA I and Group II TCA and require that a pilot of a VFR flight traversing a TRSA I establish radio contact with the appropriate ATC facility before entering the designated airspace.

The FAA disagreed with the Board's recommendation that two levels of TRSAs should be created because such a requirement would add considerable confusion to the TCA/TRSA concept. In response to the Board's intent, the FAA stated that its efforts to increase the number of TCAs and TRSAs would provide a similar level of safety. The Safety Hoard agreed with the FAA's assessment. Safety Recommendation A- 78-80 was classified as "Closed-Acceptable Alternate Action."

In response to recommendation A-78-81, the FAA had issued an NPRM that provided for upgraded transponder equipment. However, after reviewing the comments received, the FAA decided that the increased number of group II TCAs that require, the use of transponder equipment would satisfy the Board's intent. The Board agreed and classified recommendation A-78-81 as "Closed—Acceptable Alternate Action."

The Board's investigation of a mid-air collision of two general aviation aircraft, a North American Rockwell Aero Commander Model 560E and a Cessna Model 182Q, over Livingston, New Jersey, on November 20, 1982, resulted in two recommendations pertinent to the accident at Cerritos. These recommendations are:

A-83-54

> Consolidate information of visual scan techniques in Advisory Circular AC90-48C, "Pilots Role in Collision Avoidance," and 'information suoh as that contained in the Aircraft Owners and Pilots association's program "Take Two and See," regarding visual scan techniques, in one or more publications that are referred to by pilots on a continuing basis.

A-83-55

> Include questions regarding visual scanning techniques for airborne targets in written examinations for pilot licenses.

established a mobile air traffic control navigational air communication and power system.

The FAA's incident reporting system was improved.

Based upon these, actions recommendations A-72-156, -157, -158, -161, and -164 were classified as "Closed-Acceptable Action." Safety Recommendations A-72-160, -162, and -163 were classified as "Closed--Acceptable Alternate Action." The Safety Board did not agree with the actions taken by the FAA with respect to recommendations A-72-159, -161, and -165. These recommendations were classified as "Closed--Unacceptable Action."

As a result of its investigation of an accident involving a North Central Airlines Convair 340/440 and an Air Wisconsin DHC-6 over Lake Winnebago near Appleton, Wisconsin, on June 29, 1972, the Safety Hoard issued the following recommendations to the FAA:

A-73-27

Develop and publish standards for visual search techniques to be used by instructors and check pilots on all training, certification, and proficiency check flights when pilots are operating in VMC.

A-73-2 8

Establish a requirement for pilots to be trained in the techniques of time sharing between visual scanning for airborne targets and cockpit duties.

A-73-2 9

Require that all pilots and flightcrew members training, certification, and proficiency check forms contain a specific item on scanning and time sharing.

A-73-30

Require that all pilots and flightcrew members be graded in scanning and time sharing techniques when training, certification, and proficiency check flights are conducted under VMC.

A-73-31

Advise the Hoard of the status of the FAA's evaluation project of April 7, 1972, on aircraft conspicuity research and, if that project has not been completed, take action to complete the project on a priority basis.

A-73-32

> Expedite the development and issuance of national standards for systems to provide protection from midair collisions so that the industry can proceed without further delay to develop and market economically viable hardware.

On June 3, 1974 the Safety Board classified Recommendations A-73-27 and A-7338 as "Closed-Unacceptable Action," because the FAA had chosen not to develop the standards and requirements for visual scanning training as intended by the Board.

In response to recommendations A-73-29 and A-7330, the FAA informed the Board in its letter of June 26, 1973, that the en route inspection forms include specific items associated with scanning and cockpit vigilance. The Board agreed that the en route inspection forms complied with the intent of these recommendations and classified them as "Closed-Acceptable Alternate Action."

In its letter of June 26, 1973, the FAA informed the Board of the status of the FAA's aircraft conspicuity research project. This action complied with the intent of Recommendation A-73-31 and it was subsequently classified as "Closed-Acceptable Action."

In response to recommendation A-73-32, the FAA informed the Board that all technical approaches with the potential for providing collision avoidance were being investigated. However, the FAA decided not to formulate or issue any standards for collision avoidance systems since the FAA's main effort was to develop the discrete address beacon system (DABS). In its evaluation dated June 3, 1974, the Board found the FAA's efforts to develop DABS to be an acceptable approach and classified recommendation A-73-32 as "Closed-Acceptable Alternate Action."

As a result of the Board's investigation of a mid-air collision involving a Pacific Southwest Boeing 727 and a Cessna 172, over San Diego, California, on September 25, 1978, the Board issued the following recommendations to the FAA:

A-78-77

> Implement a terminal radar service area (TRSA) at Lindbergh Airport, San Diego, California.

A-78-78

> Review procedures at all airports which are used regularly by air carrier and general aviation aircraft to determine which other areas require either a terminal control area or a terminal radar service area, and establish the appropriate one.

A-78-82

> Use visual separation in terminal control areas and terminal radar service areas only when a pilot requests it, except for sequencing on the final approach with radar monitoring.

On August 4, 1971, a Continental Airlines Boeing 707 and a Cessna 150J were involved in a mid-air collision over Compton, California. As a result of its investigation, the Safety Board issued the following recommendation to the FAA on April 5, 1972:

A-72-30

> Disseminate this report to all pilot schools and bring this message to the attention of all flight instructors.

The FAA concurred in full with this recommendation and the report was subsequently sent to all of the FAA-certificated flight schools and ground schools and to state aviation officials. This recommendation was classif ied as "Closed-Acceptable Action," on August 30, 1972.

In June 1972 the Safety Board completed a special accident prevention study that analyzed the commonality of mid-air collisions and that updated the Board's previous study on this topic. The following recommendations were issued to the FAA as a result of this study:

A-72-156

> Take additional steps through their accident prevention specialists to alert the general aviation community of the increasing potential of the midair collision hazard in the vicinity of airports.

A-72-157

> Develop a total midair collision prevention system approach to include training, education, procedures, ATC equipment and practices, and the development of collision avoidance systems and proximity warning instruments that are cost feasible to the general aviation community.

A-72-156

> Require general aviation aircraft, when equipped, to utilize at all times both landing lights and anticollision lights during the approach and takeoff phases of operation and while operating in terminal or other high-density areas.

A-72-159

> After a designated date, require the daytime use of high-density white lights on all air carrier aircraft.

A--72-160

> Expedite the implementation of standard traffic pattern altitudes at all airports.

A-72-l 61

Review and reconsider the feasibility of requiring radar reflectors on all civil aircraft.

A-72-l 62

Expedite the planned implementation of terminal control area and terminal radar separation of VFR and IFR traffic and examine the potential benefits of high-speed climb and descent corridor access and egress therefrom.

A-72-163

Designate high-speed climb and descent corridors between the top of the TCA (Terminal Control Areas) and the floor of the PCA (Positive Control Areas) for high density traffic areas.

A-72-l 64

Study the feasibility of providing funding support and implementation of small mobile control facilities for periods of high-density traffic operation at uncontrolled airports to reduce collision hazard.

A-72-165

Develop a system to evaluate the effectiveness of improvement and developments in midair collision avoidance systems, to assess, measure, and analyze hazard trends.

On October 2, 1972, the FAA responded to these recommendations. The actions taken by the FAA included:

Created a media campaign to alert the general aviation community of the need to be more alert for traffic in the vicinity of airports.

Developed a system approach for the collision avoidance system and the pilot warning indicator.

Continued research and evaluation of aircraft lighting.

Developed standardized traffic patterns at uncontrolled airports.

Continued funding of a program to evaluate passive radar enhancement for small aircraft.

Expedited stage II of the national terminal radar program, and the 'established terminal control areas and modified ATC procedures to ensure better separation of aircraft.

Lowered and raised the respective' floor and ceiling of the positive control area and the TCA in heavy traffic areas to provide total positive control.

In response to recommendation A-83-541 the FAA developed an item; "Collision Avoidance "(Scanning for Other Aircraft, for inclusion in the Airmen's Information Manual), and. published several articles with consolidated information on visual scanning techniques. Safety Recommendation A-83-54 was classified as "Closed— Acceptable Action," on July 22, 1985.

In its letter of November 11, 1985, the FAA informed the Hoard that it had included questions on visual scanning techniques in the private pilot tests, and that the commercial pilot, flight instructor, and ground instructor tests would have questions on visual scanning techniques included at the next publishing cycle. Based upon this action, Safety Recommendation A-83-55 was classified as "Closed-Acceptable Action."

As a result of the Board's investigation of a mid-air collision at San Luis Obispo, California, on August 24, 1984, involving a Beechcraft model C99 and a Rockwell Aero Commander 112TC, 13 recommendations were issued to the FAA. Two of these recommendations are pertinent to the accident at Cerritos. These recommendations are:

A-85-64

> Expedite the development, operational evaluation, and final certification of the Traffic Alert and Collision Avoidance System (TCAS) for installation and use in certificated air carrier aircraft.

A-65-65

> Amend 14 CFR Parts 121 and 135 to require the installation and use of Traffic Alert and Collision Avoidance System (TCAS) equipment in certificated air carrier aircraft when it becomes available for operational use.

On May 8, 1987, the FAA informed the Hoard that a Notice of Proposed Rulemaking had been initiated to require that air carrier airplanes be equipped with a traffic alert and collision avoidance system. In its response of June 4, 1987, the Hoard stated that it found the FAA's action to be responsive to these recommendations and requested that the FAA expedite its efforts to the maximum extent possible in order that the proposed system be implemented as soon as possible. Pending further correspondence on this issue, Safety Recommendations A-85-64 and -65 were classified as "Open-Acceptable Action."

Following the Hoard's investigation of a near mid-air collision that occurred on December 20, 1984, near New Orleans, Louisiana, and involved a Lufthansa Boeing 747 and a single engine general aviation airplane, the following recommendations were issued to the FAA:

A-85-112

> Revise the localizer backcourse runway 19 instrument approach procedure or the terminal control area at the New Orleans International Airport to provide a vertical buffer between aircraft following the runway 19 instrument approach procedure and uncontrolled visual flight rules (VFR) aircraft operating below the floor of the terminal control area.

A-85-113

Review instrument approach procedures at airports designated as the primary airport within a Terminal Control Area (TCA) or Airport Radar Service Areas (ARSA) to identify potential conflicts involving an aircraft following a published instrument procedure at the floor of the TCA or ARSA and aircraft operating just below the floor of the TCA or ARSA and, if indicated, modify the instrument approach procedure and/or the TCA/ARSA boundaries to provide for positive vertical separation between the aircraft.

A-85-114

Institute measures, including appropriate changes to FAA Handbook 7400.2C and FAA Order 8260.19A, to improve coordination bet ween personnel involved in the design of the terminal control area and airport radar service area airspace and those involved in the design of the instrument approach procedures to prevent the creation of potential hazards to the users of the air traffic system.

On August 13, 1986, the FAA responded to recommend&ions A-85-112, -113, and -114. In regard to recommendations A-85-112 and -113, the FAA stated that it believed that the existing regulations and published recommended operating practices were sufficient to separate aircraft and to minimize the potential for midair collisions. The FAA stated that no further action would be taken, and the Board classified recommendations A-85-112 and A-85-113 as "Closed--Unacceptable Action," on October 23, 1986.

In response to recommendation A-85-114, the FAA informed the Board that it had reviewed the existing and revised procedures involved in the design of TCAs and Airport Radar Service Area airspace and provided information that the existing regualtions and operating practices were sufficient to minimize the ptential for midair collisions. Subsequently, in its Ietter to the FAA dated October 23, 1986, the Board classified recommendation A-85-114 as "Closed--Acceptable Action."

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