SA-320 File No. 1-0090

CIVIL AERONAUTICS BOARD

ACCIDENT INVESTIGATION REPORT

Adopted: April 15, 1957 Released: April 17, 1957

TRANS WORLD AIRLINES, INC., LOCKHEED 1049A, N 6902C, AND
UNITED AIR LINES, INC., DOUGLAS DC-7, N 6324C,
GRAND CANYON, ARIZONA, JUNE 30, 1956

The Accident

At approximately 1031,[1/] June 30, 1956, a Trans World Airlines Lockheed 1049A, N 6902C, and a United Air Lines Douglas DC-7, N 6324C, collided at about 21,000 feet[2/] over Grand Canyon, Arizona. Both aircraft fell into the Canyon near the confluence of the Colorado and Little Colorado Rivers. There were no survivors among the 128 persons aboard the flights (70 aboard TWA and 58 aboard United). Both aircraft were destroyed.

History of the Flights (See attachment 1 as reference.)

1. Trans World Airlines

On June 30, 1956, at 0901, Trans World Airlines Flight 2, a regularly scheduled passenger service, took off from runway 25 of the Los Angeles International Airport. Flight 2 was on an instrument flight rules (IFR) flight plan from Los Angeles, California, to Kansas City, Missouri, via Green Airway 5, Amber Airway 2, Daggett direct Trinidad, direct Dodge City, Victor Airway 10 Kansas City. The flight plan also proposed a cruising altitude of 19,000 feet, a true airspeed of 270 knots, and a departure time of 0830. The Trans World flight crew consisted of Captain Jack S. Gandy, Copilot James H. Ritner, Flight Engineer Forrest D. Breyfogle, Flight Engineer Harry H. Allen (aboard as an additional crew member), and Hostesses Tracine E. Armbruster and Beth E. Davis.

Preparations for Flight 2 were routine except that departure was delayed a few minutes by minor maintenance on the aircraft. The flight was dispatched with 3,300 gallons of fuel and the load manifest showed the gross weight of the aircraft at takeoff was 108,115 pounds, well under the maximum allowable of 113,200 pounds. The load was properly distributed with respect to center of gravity limitations of the aircraft.

1/ Times herein are Pacific standard and based on the 24-hour clock.

2/ Altitudes herein are mean sea level, distances are nautical miles unless otherwise indicated.

As requested, the flight, after takeoff, contacted the Los Angeles tower radar departure controller, and was vectored through an overcast which existed in the Los Angeles area. After reporting "on top" (2,400 feet) the flight switched to Los Angeles Air Route Traffic Control Center (referred to as Los Angeles Center) frequency, 118.9 mcs., for its en route clearance. This clearance specified the routing as filed in the flight plan, however, the controller specified that the flight climb to 19,000 feet in VFR conditions. Immediately thereafter TWA 2 asked for a routing change to Daggett via Victor Airway 210. This was approved in a routine manner.

At 0921, through company radio communications, Flight 2 reported that it was approaching Daggett and requested a change in flight plan altitude assignment from 19,000 to 21,000 feet. ARTC (Los Angeles Center) advised they were unable to approve the requested altitude because of traffic (United Air Lines Flight 718). Flight 2 requested a clearance of 1,000 feet on top. Ascertaining from the radio operator that the flight was then at least 1,000 on top, ARTC cleared the flight.

At 0959 Trans World 2 reported its position through company radio at Las Vegas. It reported that it had passed Lake Mohave at 0955, was 1,000 on top at 21,000 feet, and estimated it would reach the 321-degree radial of the Winslow omni range station (Painted Desert) at 1031 with Farmington next. This was the last radio communication with the flight.

2. United Air Lines

United Air Lines Flight 718 was regularly scheduled from Los Angeles to Chicago, Illinois. On June 30, 1956, it took off from runway 25L (left) of the Los Angeles International Airport at 0904 (three minutes after TWA 2). Flight 718 was on an IFR flight plan to Chicago via Green Airway 5 Palm Springs intersection, direct Needles, direct Painted Desert, direct Durango, direct Pueblo, direct St. Joseph, Victor Airway 116 Joliet, Victor Airway 84 Chicago Midway Airport. The flight plan proposed a true airspeed of 288 knots, a cruising altitude of 21,000 feet, and a departure time of 0845. The flight crew consisted of Captain Robert F. Shirley, First Officer Robert W. Harms, Flight Engineer Gerard Fiore, and Stewardesses Nancy L. Kemnitz and Margaret A. Shoudt.

Flight preparations and dispatch of United 718 were routine and the aircraft departed with 3,850 gallons of fuel. The company load manifest showed the gross weight of the aircraft at takeoff to be 105,835 pounds, which was less than the maximum allowable of 114,060 pounds; the latter weight was restricted from a maximum of 122,200 pounds for the aircraft because of a landing limitation at Chicago. The load was properly distributed with respect to the center of gravity limitations of the aircraft.

After takeoff the flight contacted the Los Angeles tower radar controller, who vectored it through the overcast over the same departure course as TWA 2. United 718 reported "on top" and changed to Los Angeles Center frequency for its en route clearance. This corresponded to the flight plan as filed; however, the controller specified that the climb to assigned altitude be in VFR conditions.

Flight 718 made position reports to Aeronautical Radio, Inc., which serves under contract as United company radio. It reported passing over Riverside and later over Palm Springs intersection. The latter report indicated that United 718 was still climbing to 21,000 and estimated it would reach Needles at 1000 and the Painted Desert at 1034.

At approximately 0958 United 718 made a position report to the CAA communications station located at Needles. This report stated that the flight was over Needles at 0958, at 21,000 feet, and estimated the Painted Desert at 1031, with Durango next.

At 1031 an unidentified radio transmission was heard by Aeronautical Radio communicators at Salt Lake City and San Francisco. They were not able to understand the message when it was received but it was later determined by playing back the recorded transmission that the message was from United 718. Context was interpreted as: "Salt Lake, United 718 . . . ah . . . we're going in."

Investigation

When neither flight reported passing the Painted Desert line of position, CAA and company ground communications attempted to contact them. This was unsuccessful and a radio search was then made by several communications stations along the proposed routes, using numerous radio frequencies available to the flights. At 1151 a missing aircraft alert was issued, followed by implementation of search and rescue procedures.

That evening a pilot who operated scenic flights over the Grand Canyon heard about the missing aircraft and recalled having seen light smoke rising out of the Canyon earlier in the day. With his brother, he returned to the area, flew into the Canyon, and during a low pass was able to identify the empennage of the TWA Constellation. He reported the finding immediately and the next day made another flight, during which it was ascertained that there was a second wreckage approximately one mile from the first. There were no signs of survivors on either occasion.

On July 1 an Air Force helicopter from a Search and Rescue unit landed, under hazardous conditions, at the TWA site. After careful consideration, planning, and trial flights, a successful landing was made by an Army helicopter pilot at the United wreckage. On both initial landings a medic accompanied the helicopter pilot and, after examination, reported that no one had survived either crash. During the following days Army units provided transportation, under extremely hazardous conditions, to and from the sites by helicopter, making it possible to reach the otherwise nearly inaccessible area.

The L-1049 Constellation crashed in a draw on the northeast slope of Temple Butte, which is on the west bank of the Colorado River within the Grand Canyon. The main wreckage site was at an elevation of 3,400 feet. The wreckage was found strewn across the draw along a southwesterly heading,

with portions of the nose section on the south bank of the draw and sections of the cabin fuselage on the north bank. A relatively short wreckage distribution path showed that the aircraft contacted the ground at a steep angle. The distribution and condition of parts indicated the Constellation was inverted at initial impact.

Severe disintegration of the L-1049 occurred during ground impact, followed by an intense ground fire. Together, these caused nearly total destruction of major portions of the aircraft. It was possible, however, to identify a sufficient number of parts to show that with the exception of the L-1049 empennage, portions of the aft fuselage, and light pieces of aft cabin interior, all of the aircraft was at the main wreckage area. Here several pieces of the DC-7 were located. All of these were identified as being parts of the DC-7 left outer wing structure.

The main wreckage area of the DC-7 was located 1.2 statute miles northeast of the L-1049 area. Examination revealed the DC-7 struck the south face of Chuar Butte opposite the Little Colorado River. Impact was about 10 feet below the top of this ridge at an elevation of 4,050 feet. Initial impact was on a northeast heading with the aircraft nosed down and its right wing below a level attitude.

Impact forces caused severe disintegration of the DC-7 with major components falling into an inaccessible deep chimney and upon sheer ledges below the impact site. An intense ground fire followed impact. Except for a large portion of its left wing, the DC-7 major components were accounted for by identification of parts and pieces found at or reasonably near the main wreckage area.

During the difficult and hazardous structural investigation every effort was made to determine whether or not an inflight collision had occurred and, if so, the manner in which the aircraft collided. Results of this work disclosed several areas of damage which conclusively established that such collision did occur. These areas also provided material for an analytical study relating to the physical relationship of the aircraft to each other at the instant of the inflight impact.

One of the significant areas involved in the inflight contact was the left outer wing panel of the DC-7. Pieces found represented the wing panel from its tip inboard to station 453, a length of about 20 feet. Much of this structure bore evidence of the inflight collision. Some portions of the upper surface, leading edge, and aileron were missing.

The largest single piece of left wing outer panel was found between Temple and Chuar Buttes about one-third mile west of the TWA wreckage site. This piece consisted of the outer portion of the panel from the tip inboard to approximately station 627. To this station the upper and lower wing skin and the leading edge were generally intact. Portions of lower skin were in place for another six feet inboard. Collision evidence in the form of dents, scratches, tears, and bends were found on much of the lower surface of this

entire structure. Part of this damage consisted of an upward and inboard deformation in the wing tip cap between the position light and aileron cove. Black rubber smears and red paint smudges were evident at several locations in the deformation. Examination showed the smears on the DC-7 were from the L-1049 deicer boot; also, the paint smudges were from the L-1049.

A fragment of DC-7 wing tip assembly was found separately. This 11-inch piece was part of the aileron cove from the extreme wing tip area. Fragments of top and bottom wing skin were still attached to this piece. Just aft of the tear the tip radius was deformed inboard, rearward, and upward with heavy deposits of L-1049 red paint in the crumpled area. Further, the tip lower surface inboard to the tip attach point was deformed upward and marked by scratches running inboard and aft. Also, in this general area on the lower wing surface there were numerous black rubber smears and additional scratches. The smears and scratches ran diagonally aft and inboard about 23 degrees in relation to the wing center spar line.

Two pieces of the DC-7 left aileron were found representing the tip area inboard to about station 656. These pieces were severely buckled inboard and upward and both bore heavy deposits of black rubber smears on their lower surfaces.

Between stations 627 and 603 the wing leading edge of the DC-7 was deformed rearward and outboard. Rearward and inboard scratches on the lower leading edge were continuous through areas of deep buckling; indicating they were made before the leading edge struck the object causing buckling. Aft of the leading edge on the lower wing surface there were more scratches running aft and inboard at an angle of approximately 25 degrees relative to the center spar. In this specific area there was no evidence of the black rubber smears.

At the L-1049 wreckage area a section of lower wing skin from the DC-7 was found. This section was from the left wing where the aircraft registration is painted and bore portions of numbers "6" and "3." Scrape marks corresponded directionally to those previously described. Imbedded in a tear on this part was a piece of Constellation headlining used in the aft cabin ceiling. Brown smudges running in the same general direction as the scratches were determined by chemical analysis to be material used to seal Constellation fuselage seams and stringers in the pressure cabin area.

A second area of damage significant to the investigatory objectives and closely allied with the DC-7 wing damage was the Constellation empennage. This major component had struck the ground inverted but came to rest in an upright position about 550 yards north of the concentration of L-1049 wreckage. It was generally intact except for the left and right fins and rudders. Respectively, these were found about 30 and 10 yards removed. The distance of the empennage from the rest of the L-1049, together with the evidence of severe damage where it was separated from the aft fuselage, showed this major component had separated in flight after collision impact. Heavier pieces of the L-1049 aft fuselage structure and aft interior equipment were found west of

the main TWA wreckage site. Light interior materials from the aft fuselage were found on Cape Solitude 1-1/2 miles east, indicating that they were torn or spilled out at a sufficient altitude to drift this distance.

Two pieces from the Constellation empennage were recovered away from the main empennage at sufficient distance to indicate separation prior to ground impact. These, consisting of sections of the left upper fin leading edge and bearing portions of red and white stripes of the Constellation color scheme, showed collision evidence. One piece was concaved on its leading edge, in the area of the red stripe, by an object moving right to left. The concave area fitted precisely with the damage on the DC-7 left wing tip. The red paint found on the wing tip came from this red stripe, and the black marks resulted from contact with the fin leading edge deicer boot. The second piece, which fitted below the concaved piece, was crumpled to the left by the same force that damaged the concaved piece.

The L-1049 aft fuselage was a third area of collision damage. Most significant was a piece of fuselage skin about 1-1/2 x 4 feet in size. Identification showed it came from the upper right side of the Constellation fuselage just forward of the tail. Its outer surface was painted white. This metal piece was bent inward about 90 degrees so that its inner surfaces were folded toward each other. There were red, blue, and black marks in various directions on the white outer surface paint in the area aft of the bend. In addition to these marks there were gray deposits in a random pattern creating a stippled effect over the entire surface. Together with these there were also long grayish smears progressing in the same direction as the stippling. Pileup of the individual marks within the deposits was heavier on the upper edge. This evidence indicated that the gray deposits were made by an object moving up and along the circumferential frames of the Constellation fuselage.

The final area of important damage was also in the aft fuselage of the L-1049. It was a series of three propeller cuts in the lower and bottom fuselage in the vicinity of the rear baggage compartment. The cuts were generally upward and inboard and of varying lengths. They were essentially parallel about 35 inches apart with the middle cut about 52 degrees relative to the longitudinal axis of the aircraft. Red and blue paint marks at the edge of one cut in the baggage bin area coincided with the paint scheme on the DC-7 propeller.

Two additional propeller cuts were located in the L-1049 forward fuselage. One cut was approximately in line with the L-1049 No. 3 propeller arc and the other was about four feet forward. This damage was not consistent with the other collision damage and the cuts were probably made by the propeller of the Constellation during ground breakup.

Other areas of both aircraft were involved in the collision. Some were secondary or cumulative to the evidence already described and others, although important for other reasons, were not indicative of the inflight impact.

Investigation showed that normal and routine preparations were made for the flights. The TWA Constellation had received a periodic maintenance check at Los Angeles and except for minor discrepancies, not affecting airworthiness, was in good condition. The DC-7 was checked at Los Angeles and at departure there were no mechanical discrepancies or carryover items. The flight engineers had performed preflight and walkaround inspections of their respective aircraft.

Both flights were planned as high-altitude operations (above 14,500 feet west of the 100-degree Meridian) which under current regulations and operating specifications permitted them to be planned and flown off airways over direct courses to take advantage of the most favorable weather and wind factors as well as the shortest distance between origin and destination of the long-range nonstop flights. Before flight, however, a definite flight plan is required over the direct route with numerous reporting points indicated to clearly define the proposed route to be flown. To this end numerous company high-altitude routes have been established. From these the most favorable is selected for an individual operation commensurate with existing conditions.

United Airlines' operational policy permitted a high-altitude flight to be conducted on an IFR or VFR flight plan but the company did not permit its flights to be flown in instrument weather conditions, regardless of the flight plan, during that portion of the flight off airways. In this regard Trans World Airlines' policy, at the time of the accident, permitted off airways flights in instrument weather conditions but only on an IFR flight plan with an assigned altitude. When operating 1,000 on top the company required adherence to visual flight rules.

The pilots were briefed on the anticipated weather conditions before flight time. These indicated conditions well within limits for takeoff and for the planned duration of the flights. Captain Gandy, with nearly 15,000 flying hours, had flown the subject route approximately 177 times and was well qualified. Captain Shirley, with 17,000 hours, had flown the operation since October 1955, and he also was well qualified. Similarly, the other crew members of both flights were experienced. All, according to documentary evidence, were rested, in good physical condition, currently qualified, and certificated for their positions.

The flights reported in a normal manner as they progressed eastward. Except for the final transmission of United 718, the reports were without indication of any difficulty. The individual company dispatch offices followed the progress of their flight in a regular manner according to their responsibility.

Approaching Daggett the TWA flight asked for a change in its flight altitude from 19,000 feet to 21,000 feet on its IFR clearance, and if unable, 1,000 on top. The TWA radio operator who received this request from the fligh called Los Angeles ARTC and at 0921 advised, "TWA 2 is coming up on Daggett requesting 21,000 feet." The Los Angeles controller then contacted the Salt

Lake ARTC controller and said, "TWA 2 is requesting two one thousand, how does it look? I see he is Daggett direct Trinidad, I see you have United 718 crossing his altitude - in his way at two one thousand." According to the recording of this conversation the Salt Lake controller replied, "Yes, their courses cross and they are right together." The Los Angeles controller then called the TWA radio operator and said, "Advisory, TWA 2, unable approve two one thousand." At this time the radio operator interrupted and said, "Just a minute. I think he wants a thousand on top, yes a thousand on top until he can get it." After determining from the flight, through the TWA radio operator, that it was then 1,000 on top the Los Angeles controller issued the following amended clearance, "ATC clears TWA 2, maintain at least 1,000 on top. Advise TWA 2 his traffic is United 718, direct Durango, estimating Needles at 0957." The TWA ground radio operator stated that this clearance was given TWA 2 and it was repeated back to him verbatim by the flight. The operator said that in this transmission he included the information concerning United 718, adding that it was at 21,000 feet which he concluded from the overall situation although the altitude was not part of the information from the controller. The TWA operator testified that he recognized Captain Gandy's voice and that the captain acknowledged the information on the United flight as "traffic received."

The two controllers participating in this action were called to testify at the Board's public hearing. In response to questions they stated that because TWA 2 would soon pass from the Los Angeles ARTC area of responsibility to the Salt Lake area it was necessary to coordinate the TWA request for altitude change. Both stated that at this time the flights were IFR traffic operating in controlled airspace and ARTC was required to separate them from each other as well as from any other aircraft on IFR clearances. The controller who gave the clearance said he offered the United information to TWA merely as an explanation for the denial of 21,000 and not as a traffic advisory.

The Director of the CAA Office of Air Traffic Control explained that when TWA requested 21,000 feet the flight had not reached Daggett nor had the United flight reached Needles. They were not traffic for each other at that time but in projecting their tracks eastward both would cross Red Airway 15 with ill-defined horizontal separation. On this airway ARTC was required to separate the flights; thus TWA was denied 21,000. The witness added that this separation was an ARTC responsibility for instrument flights only in the controlled airspace and that Red Airway 15 was the last such area for the flights to traverse until they were well beyond the accident scene. He said that ARTC maintains only progress information with respect to IFR flights flying through uncontrolled airspace and that this information is used for the purpose of providing a safely spaced flow of instrument traffic into the next controlled airspace to be entered. He stated that air traffic control does not provide any control service or function in uncontrolled airspace. The witness explained that flights are not bound by clearance or flight plan, whether VFR or IFR, while operating in uncontrolled airspace and that instrument traffic must only leave and reenter a control area according to traffic control clearance. The controllers' manual of control procedures (ANC Manual) states that, "Clearances authorize flight within control zones and control areas only; no responsibility for separation of aircraft outside these areas is accepted."

When TWA amended its flight plan from an assigned 19,000 feet to 1,000 feet on top, no information concerning this was given to United 718. The Director of Air Traffic Control stated that none was required though the flights were in controlled airspace at the time. The clearance to TWA 2 was to maintain 1,000 feet on top while it was in a control area. The witness said the flight was not restricted to any specific altitude in control areas except that it be at least 1,000 feet above the general cloud layer. When outside controlled airspace and under certain conditions of limited visibility flight should be conducted at an altitude conforming to the "Quadrantal Rule."[3/] The witness stated that the controller therefore did not know what altitude Captain Gandy would select as a cruising altitude or if he might later change the altitude from time to time. The witness stated that with respect to separation the TWA flight at this time was a VFR flight and that the basic VFR minimums applied for it to maintain flight in VFR conditions.[4/]

Civil Air Regulations do not provide a definition for 1,000 on-top operation either within or outside controlled airspace; however, with respect to on-top operations in control areas the Flight Information Manual states, "'At least 1000 feet on top' (1OTOP) may be filed in an IFR flight plan, or assigned by ATC in an IFR clearance, in lieu of a cruising altitude. Even though this type of operation places the responsibility for avoidance of collision with other aircraft on the pilot, the flight is an IFR operation and must obtain an amended clearance for a specific altitude before proceeding into IFR weather conditions." It further states, "Air Traffic clearances which specify 'at least 1000 feet above all clouds' in lieu of a cruising altitude permits flight to be conducted at any altitude at or above the minimum en route altitude (MEA) which is 1000 feet or more above the cloud layer . . ."

The present concept for separation of aircraft and avoidance of collision in VFR weather conditions, regardless of flight plan or clearance, depends on the flight crews' ability to visually provide separation between aircraft. Civil Air Regulations expressly place this responsibility on the pilots[5/] and the concept is commonly referred to as the "see and be seen" principle. Rules for avoidance and right-of-way are set out in the Regulations also.[6/] With respect to an IFR flight operating in VFR weather conditions the Flight Information Manual states, "During the time an IFR flight is operating in VFR weather conditions, it is the direct responsibility of the pilot to avoid other aircraft, since VFR flights may be operating in the same area without knowledge of ATC." In consonance with these provisions the vast percentage of flying today is separated by the "see and be seen" philosophy with little or no external traffic control assistance.

3/ Civil Air Regulations. Part 60.32 (b) 1, 2, 3, and 4.

4/ Civil Air Regulations. Part 60.30 (b) (1).

5/ See CAR Part 60.12 (c)

6/ See CAR Part 60.14 (a) through (c) and CAR Part 60.15.

At 0958 United Flight 718 reported its position to the CAA communications station located at Needles. This report indicated that the flight was over Needles at that time, its altitude was 21,000 feet, and it anticipated reaching the Painted Desert line of position at 1031 (revising the previous estimate of 1034). The flight indicated it would thereafter report over Durango. The Needles communicator forwarded this report, according to routine procedure, to the Albuquerque center at 1001 and to the Salt Lake center about 1013. The communicator stated that forwarding the report to Salt Lake was delayed by an interphone tieup. The controller at Salt Lake receiving the report was the one who previously was involved in the decision which denied TWA 2 the request for 21,000 feet as a cruising altitude when the flight was approaching Daggett at approximately 0921.

At 0959 Trans World Flight 2 reported its position to company radio located at Las Vegas. The flight reported it had passed over Lake Mohave at 0955, was 1,000 on top at 21,000 feet, and estimated reaching the 321-degree radial of the Winslow omni range station (the Painted Desert line of position) at 1031, with Farmington the next reporting position. In response to this the ground communicator repeated back the information, added the barometric pressure for Las Vegas, and told the flight that this pressure was falling rapidly. At 1001 the Las Vegas TWA communicator promptly forwarded this position report over long-line interphone to the Salt Lake center. This report was received by the CAA sector controller at 1001. The same controller received the position report of United 718 at 1013 from the CAA Needles communicator.

During the public hearing the Salt Lake controller and the CAA Director of Air Traffic Control were questioned as to whether or not traffic advisory information should have been issued the flights when the controller had received position reports from both flights and knew both were flying at the same altitude, estimating the Painted Desert line of position at the same time on converging courses. The controller stated that when the reports were received by him he had no knowledge of the track that either flight would make to the line of position because both were in the uncontrolled area and a specific track was not required. He said the Painted Desert line of position is nearly 175 miles long with no definite position within this distance. The estimates from the flights, therefore, did not mean they would converge there but merely that both would pass the line eastbound at that time. He testified that he was not required to give advisory information to flights which were in uncontrolled airspace and it was only a discretionary duty in the controlled area. He also said this advisory service would not be possible as a day-to-day practice without control of flights and more definite position information, as well as additional facilities and personnel.

The CAA Director of Air Traffic Control testified concerning the situation, stating that it was not the policy or concept of Air Traffic Control to provide traffic information outside of controlled airspace. He said normally such information would be of little value. Many aircraft unknown to Air Traffic Control may be operating in this area; further, Air Traffic Control has no authority over those aircraft that are known. The witness testified that with

respect to these two particular flights, the controller certainly knew about them; however, he explained that advisory information must be viewed in its overall application in day-to-day operations. He stated that advisory service for traffic in uncontrolled areas would be tantamount to positive control of all traffic which would require personnel, facilities, and equipment not presently available. He added that this was known to be correct, having several years ago attempted to provide this service on a test and evaluation basis. He added that the workload of an advisory service was found to be nearly equal to that required for a control service. He concluded that the present complement of persons assigned to perform the controller's functions in the uncontrolled areas could not be considered sufficient to offer either an advisory service or perform a control service.

Investigation relating to the progress of the flights shows they were according to the established performance of the aircraft. Both flights made good their estimates between position reports until the segments immediately prior to the Painted Desert line of position; for United from Needles and for TWA from Lake Mohave.

According to the United estimate the flight would reach the Painted Desert at 1031, or 33 minutes after passing Needles. Investigation showed the accident occurred at 1031, approximately 17 miles or nearly 3-1/2 minutes' flying time from the position of expected progress. Compared to another United flight, 708, a DC-7, which climbed over the same course to cruise at 21,000 feet approximately one hour earlier, Flight 718 should have reached the Painted Desert in its estimated elapsed time. Cruise performance of the aircraft also showed the estimate could have been made.

TWA Flight 2 also was making good its estimates as it climbed toward Lake Mohave. The estimates were in accord with accepted performance of the Constellation and the flight estimated it would reach the Painted Desert at 1031, or 36 minutes after passing Lake Mohave. This flight also was approximately 3-1/2 minutes' flying time from its estimated position when the collision occurred.

Winds aloft were carefully reviewed to determine whether or not they could have been a factor in the delays. It was learned that these winds were light in consideration of altitude and varied little from the winds forecast.

Determination of the time of the accident was an important phase of the Board's investigation. The severe damage sustained by the United Aircraft leaves little question but that the aircraft crashed soon after the collision and therefore the last transmission from its crew came very close to the collision time. Knowing the recording that contained the transmission also contained time checks and operated relative to actual time, it was learned that the message began at 1030:53. Pilots who knew the United crew and heard the final message or its transcription felt with reliable assurance that the voice was that of First Officer Harms.

The recorded transmission itself was also examined under laboratory conditions to determine what the exact message was, whether or not anything was said which was inaudible under normal listening conditions, and whether or not the tragedy was reflected during all or just part of the message. The latter objective would assist in determining whether or not the DC-7 crew sighted the L-1049 during the transmission and if the accident occurred during it. The analysis was based on a correlation of the spoken words with a spectrographic analysis, a technique used in "Visible Speech." Tests involving binaural listening and speech stretching were also made.

The laboratory results showed the principal speaker said, "Salt Lake, area (or ah), seven eighteen . . . we are going in."7/ During the time represented by the dots a second speaker yelled two known words which were, "up . . . up." This speaker also yelled words which preceded "up." These were indefinite but fitted energy patterns of "look," "pull," or "come." The tests showed clearly that the principal speaker throughout was speaking between 100 and 200 cycles above the normal male voice pitch spectrograms. The background or second speaker's pitch was even higher, being well above that of a female voice; however, it was fairly certain that it was a male speaker. According to the laboratory study both general voice patterns, particularly as to pitch, showed the speakers were under great emotional stress, indicating that they were already in serious trouble.

An exhaustive search for eyewitnesses to the inflight collision was conducted. Many persons were contacted in the popular tourist area, as were employees of the Grand Canyon Park Service and residents of the surrounding areas. During this search no witnesses were found who saw the collision although at least one person apparently saw smoke from the crashes and dismissed it as a brush fire in the Canyon. Later, on July 10, two witnesses were made known to the Board and were called to appear at the public hearing. These witnesses stated that while driving west on Route 66 between Winona and Flagstaff they saw two aircraft collide. Their descriptions fitted the subject aircraft and especially the Constellation. Both witnesses stated that when collision occurred there was no evidence such as fire, smoke, or falling pieces and that following impact the aircraft seemed to continue on without falling but locked together.

Under intensive questioning, one of these witnesses testified that at the time she saw these two planes she saw them come together. Asked if she saw them collide she said she didn't realize at the time that they had. Questioned further as to how close they came together, she replied, "Too close." She was asked if she observed any space separating the two aircraft and she answered, "Just between the two tails." The witness was asked had she seen the two planes collide would she have said something about it to her husband. She replied that she would have but that she and her husband didn't discuss it. She further stated that she didn't recall her husband saying anything to her about the collision. The witness, a registered nurse, was asked if there had been any thought in her mind that this was a collision wouldn't she have gone to the nearest telephone and made some call to some official body of some authority. She said that she would have.

7/ Differences between initial listening and laboratory results relative to message context are recognized. See page 3.

Investigation showed that the collision occurred a short distance west of and above the wreckage locations, approximately 70 miles from the witnesses. Calculations and visual capability indicated that at this distance it would be impossible to see distinguishing physical features of the aircraft and nearly impossible to see the aircraft. Relative positions with respect to each other if visible, would be extremely deceptive. The Board does not question the sincerity of these witnesses but believes they must have seen two other aircraft; several are known to have been operating in this general area. At a considerable distance and at certain angles of observation two widely separated aircraft could well present the illusion of a collision.

A third witness reported having seen a puff of smoke in the sky over the Grand Canyon area. This witness was near Winslow, about 80 miles from the accident site, and was also proceeding in a private automobile west on Route 66. The puff of smoke seemed very high and from it two objects appeared to fall on a trajectory path and disappeared into lower clouds. This observation may have been the collision but because little detail could be seen it adds little to the investigatory objectives other than those already clearly established by more positive evidence.

To establish conclusively the importance of the information offered by these witnesses, Board investigators were stationed about 14 miles east of Flagstaff, the approximate position of the nearest witnesses as indicated by their testimony. On separate days United and Trans World flights flew the proposed routes of Flights 2 and 718, making position reports to the investigators according to a prearranged detailed plan. These were received by a CAA communications truck located with the investigators. Weather conditions on one day were better than those on the day of the accident and on the second day they were equal to or better than the accident day. Results of this work showed that the aircraft could not be seen though their exact positions were known, as were the angles on which to sight to the positions. Many reports and sightings were undertaken. Once a reflective flash was seen and binoculars were trained on it. With this assistance to the observers' normal vision the aircraft could be seen but it could not be identified as to type or make.

The Board was about to publish its report on this accident when, on February 1, 1957, it was advised of another alleged eyewitness to the collision. Shortly thereafter the witness was examined, at length, as to his observations in a deposition taken by the Board.

In substance, the witness testified that on June 30, 1956, while proceeding to Grand Canyon, he made his observations through the windshield of a Ford pickup truck in which he was traveling alone on Route 64 toward Desert View at a speed of 75-80 miles an hour up a prolonged incline in the road. At the point of observation he was between 5 and 7 miles south of Desert View or 15-17 miles south of the estimated collision point.

When questioned as to why he did not make public the fact that he had observed the accident, he answered that he did not want to embarrass himself.

Although he had several conversations with persons involved in the investigation of this accident, including Board personnel and personnel of the air carriers involved, he did not reveal the fact that he had seen the accident until seven months later.

The Board has carefully evaluated all of the testimony of this witness and concludes that it has no probative value. First, we cannot accept the witness' statement with regard to weather conditions. The record contains full and complete weather information as determined from weather reports, pilot reports, and an analysis of the synoptic situation. This testimony of the witness is in direct conflict with the known weather conditions, as clearly set forth by reliable and probative evidence contained in the record of this case.

Second, with respect to the witness' description of the relative positions and identification of the aircraft, it is unlikely that the witness could have seen these aircraft in the manner and from the place he described. This conclusion is based upon certain tests which were made by the Board immediately after the witness' deposition was taken, and the fact that the witness' observations were made while driving a truck at very high speed.

Under the circumstances, we cannot accept the witness' testimony.

The possibility that both aircraft could have been south of their courses, using the 3-1/2 minutes of unaccounted for time in this manner, is remote. A radius of action computation shows the time to be insufficient to bring the aircraft, especially TWA Flight 2, to a position much closer than 45 miles to the observers' point and thereafter flown to the known collision position.

The synoptic weather situation consisted of a thermal low centered a short distance northwest of Las Vegas, Nevada. A second low pressure area was centered in Nebraska from which a cold front extended southwestward into northern Colorado, thence westward through central Utah and Nevada as a quasi-stationary front during the day and night of June 29. Aloft the pressure distribution resulted in a southeasterly flow of moist air into northern Arizona. Numerous thunderstorms resulted during the afternoon and night of June 29 which increased the surface moisture. These factors prevailed during June 30 causing considerable low and high cloudiness and showers in the Grand Canyon area but the winds aloft had become more westerly, ranging from south-southwest at 8,000 to west at 21,000 feet. West of this area the routes were clear except for a local coastal stratus condition in the Los Angeles area and some scattered clouds en route but well below flight altitude.

The conditions described were indicated in forecasts made by the United States Weather Bureau and both company weather departments. These predicted there would be high broken clouds with light rain showers in the Colorado River area, the clouds becoming scattered at 8,000 feet by 1100. Scattered thunderstorms were expected south and east of a line defined from Denver through Milford, Prescott, and Phoenix. These were expected to dissipate in the Arizona and southeastern Utah sector after 0700 but to develop again by 1100. The freezing level was anticipated at 15,000 feet with light icing and

turbulence in the clouds. Moderate to severe turbulence was forecast in the thunderstorms. These buildups were expected to develop to 30,000 feet or higher, protruding through and above the lower coverage. Top of the lower clouds was anticipated at about 15,000 feet with good visibility above and outside the thunderstorms. The position of the sun was nearly overhead at 1031 (1131 m. s. t.).

Pilots who flew near the accident area furnished some on-the-spot weather information which essentially supported the forecast conditions. One airline captain passed about 25 miles southwest of the accident site a few minutes after the accident occurred. He stated that a lower cloud coverage commenced well east of Las Vegas with increasing coverage from Havasu Creek eastward, becoming nearly overcast 20-25 miles west of Grand Canyon Village. Cruising at 19,000 feet he noted several towering cumulus clouds, one of which was located over the immediate Grand Canyon Village area and others farther east and northeast. He saw no buildups west of Grand Canyon Village. He estimated the height of these to equal or exceed 25,000 feet and stated that they appeared to still be in the active or building stage. He was unable to estimate the size of the thunderstorms relative to diameter, length, or width. Below, he said, the top of the overcast was approximately 15,000 with few breaks but recalled one such break through which he saw Grand Canyon Airport, located 25 miles southwest of the accident site. The captain stated that he operated clear of clouds with no difficulty as he passed west and southwest of the accident site.

Other pilots flying below the overcast over the Grand Canyon saw a shaded rain area to the west. One pilot said there were breaks in the overcast with excellent visibility below it. He added that the condition described existed in all directions to the limit of his visual ability. Through the breaks he noted no evidence of any appreciable buildups.

Analysis

The several areas of damage previously described formed the foundation for a successful although arduous analytical study relative to the inflight collision sequence, the extent and effect of the collision damage, and the relative attitudes of the aircraft at the instant of impact.

The initial impact occurred with the DC-7 moving from right to left relative to the L-1049 and with the L-1049 moving to the right and aft relative to the DC-7. From analysis of physical damage in consideration of locations of the damaged components of the aircraft, it appears that first contact involved the center fin leading edge of the L-1049 and the left aileron tip of the DC-7. Instantly thereafter the lower surface of the DC-7 left wing struck the upper aft fuselage of the Constellation with disintegrating force. Without question this force caused complete destruction of the aft fuselage and destroyed the structural integrity of the left wing outer panel. As this occurred and the aircraft continued to pass laterally, the left fin leading edge of the Constellation and the left wing tip of the DC-7 made contact, tearing off pieces of both components. During this same time the DC-7 No. 1 propeller

inflicted a series of cuts in the area of the aft baggage compartment of the L-1049. This entire sequence occurred in less than one-half second and in such a manner that an interlocking of the aircraft was virtually impossible.

From the extent of damage and the locations of various components on the ground, the collision ripped open the fuselage of the Constellation from just forward of its tail to near the main cabin door. The collision also caused the empennage of the Constellation to separate almost immediately. This aircraft then pitched down and fell on a short forward trajectory to the ground. Consideration of these factors leads the Board to conclude that the collision occurred in space over a position just west of the TWA crash site.

The United aircraft appears to have sustained lesser but equally critical damage affecting flight. Most of its left outer wing separated during the collision and it appears likely that the horizontal stabilizer of the DC-7 was struck by pieces torn off the Constellation. It is also reasonable that damage to the left wing restricted aileron control. It is believed that the DC-7 fell less steeply, probably on a turning path, to the ground.

For damage to have resulted as described earlier and for other areas to have escaped inflight contact, the aircraft had to be oriented in a certain manner relative to each other when the collision occurred. Additionally, and independent of the matching of damage, a study was also made relative to the propeller cuts. Both studies gave nearly identical results relative to the angle between the aircraft at the instant of impact. This angle was found to be approximately 25 degrees relative to the longitudinal axes.

From the layout work matching the inflight contact areas, it was determined that the DC-7 left wing was above the L-1049 relative wing plane or the DC-7 was rolled approximately 20 degrees right wing down relative to the L-1049. The study also indicated the aircraft were oriented such that the vertical distance between empennages of the aircraft was less than the vertical distance between their nose sections. The difference as an angle was between 5 and 10 degrees. It is important to recognize that the aircraft attitudes described are relative or with respect to each other and do not necessarily reflect their orientation with respect to the ground.

Because some components of the aircraft were not recovered and others were destroyed, it was not possible to determine completely whether or not any malfunction occurred to either aircraft before impact. From all that could be examined there was no evidence of malfunction and from all the evidence surrounding the accident the Board believes there was none.

Analysis of all the available weather information (see attachment 2 as reference), including pilot reports, indicates that the forecast conditions for the flights were reasonably accurate. It shows that the two flights departed Los Angeles and climbed through an overcast approximately 700 feet thick to clear conditions on top. The overcast was local in nature and confined to the Los Angeles coastal area. Thereafter, the flights, except for some scattered clouds, were in clear weather as they climbed eastbound over their respective tracks.

Clear weather appears to have prevailed east of Las Vegas along the Colorado River to near Havasu Creek but becoming overcast with a few breaks beginning a short distance east of Havasu Creek. Along the proposed routes of TWA 2 and UAL 718, scattered clouds commenced shortly east of the California-Arizona border. Eastward therefrom clouds increased to broken, then overcast with some breaks in the Grand Canyon area to somewhat east of the accident site. Tops of this main weather coverage were approximately 15,000 feet with several lower layers, the lowest being about 2,000 feet above the ground.

Northwest of Grand Canyon Village, or over the western portion of the main Grand Canyon, the first of several scattered buildups appears to have existed. It appears to have been isolated with others northeast of it. The build-ups were apparently formed in the lower clouds and protruded through and above them to approximately 25,000 feet. An airline captain described the westernmost buildup as large but of an indeterminable width and length. He believed it was almost over Grand Canyon Village. Pilots below the overcast saw no evidence of it there but at least two noted a rain area northwest of this position. It is entirely likely that the rain area was from the buildup noted by the captain from above. Pilots flying below the overcast also stated that they saw breaks in the overcast but that they were few and scattered. They observed that the overcast condition covered most if not all of the Grand Canyon.

From the evidence available the Board is of the opinion that the weather conditions at 21,000 feet would not have precluded flight in VFR conditions in this accident area but that deviations may have been required to circumvent the buildups while the subject flights traversed the area.

According to company procedures United flights were not permitted to fly in instrument weather conditions while operating off airways. Similarly, TWA procedures precluded instrument flight under the flight clearance on which its Flight 2 was proceeding at the time of the accident. Each company, under the conditions during which this accident occurred, therefore required its flight to adhere to visual flight rules. Further, it is unlikely that Captain Gandy would proceed into instrument weather conditions, having previously been informed that the United flight was in the general area at 21,000 feet. The Board is therefore of the firm opinion, based on the weather conditions, company procedures, and good pilot practice, that both flights were operating according to rules prescribed for VFR conditions when the collision occurred.

The last position report from each flight indicated, at the time the report was given, that each was at 21,000 feet. Although there was no requirement for either to remain at that altitude in the uncontrolled area, with respect to Air Traffic Control, each company did require that it be notified of an altitude change. Because there was no notice and no known reason for the flights to alter altitude, it is considered reasonable to believe that the collision occurred at 21,000 feet.

Considering each flight's estimate to the Painted Desert, together with aircraft performance, it appears that both flights should have reached the

.ine of position about 17 miles, or 3-1/2 minutes' flying time, farther ;ast when the accident occurred. Although there are several possibilities, 10 definite conclusion has been reached as to the cause of the 3-1/2-minute lelay of these aircraft. One possibility is that it could have been caused)y maneuvering to provide a more scenic view for the passengers, although the evidence is not sufficient to establish this fact. Another possibility is that a less favorable wind was encountered during the subject segments than was used for estimates which slowed the progress of the flights. A third possibility is that one or more buildups in the Grand Canyon area may have required deviations and, if so, could account for the time element involved.

At approximately 1013 the Salt Lake controller was in possession of the last position report made by each of the subject flights. He was then aware that when the reports were made both aircraft were operating at 21,000 feet, were on converging courses, and were estimating the Painted Desert at the same time. He advised neither flight of this situation. In considering whether or not this should have been done, the traffic control concept, the controller's express duties, and the requirements involved to provide this information to flights must be considered.

Air Traffic Control undertakes to separate air traffic when it is operating in accordance with an IFR clearance and while it is within the confines of controlled airspace. If instrument weather conditions exist and the above requirements are met, all air traffic would be separated. However, when visual flight conditions exist instrument traffic is separated only from other like traffic and not from aircraft being flown under visual flight rules, much of the latter being unknown to Air Traffic Control. For this reason flights in visual conditions are required to provide their own separation regardless of flight plan or clearance.

Outside the controlled airspace the air traffic control concept has not embraced the responsibility for separation of air traffic regardless of flight plan, clearance, or weather conditions. In this area no control is exercised by Air Traffic Control, its principal function being to monitor the progress of flights through an uncontrolled area so that an orderly flow of instrument traffic may be accomplished into the adjacent control area. Control is not presently available in the uncontrolled airspace because sufficient facilities and means for such control do not exist.

At the present time traffic advisory information to flights is offered when and where control of air traffic is being exercised. Then, such advisory is discretionary with the controller and is not a mandatory procedure of control. Accurate and worthwhile traffic information requires that the controller be informed of the aircraft involved and have precise and timely information on the position of flights relative to their altitude and lateral and forward position along a defined track. This information must thereafter be posted and correlated with like information on other flights to determine whether or not a conflicting situation exists. In the uncontrolled airspace, as previously stated, flights are permitted greater flexibility to take advantage of wind and weather factors. Further, in this area the navigational aids

enabling a flight to report its position with the precision necessary to enable accurate advisory information are insufficient. The aforementioned factors affecting the value of traffic advisory information are evident with respect to TWA 2 and United 718. Both flights were somewhat north of their proposed tracks, both were approximately 17 miles west of where they had estimated they would be at that time, and their actual tracks intersected a considerable distance before the proposed tracks converged. Such deviations are not unusual in off-airways operation.

Although knowledge of the projected flight paths of the subject flights could have prompted the Salt Lake controller to offer both flights traffic advisory information on a voluntary basis, giving the best information available to him at the time, the Board is of the opinion that the existing control concept, Air Traffic Control policies and procedures, and the express duties of a controller did not require him to do so.

This accident, as nearly all other midair collisions, apparently occurred in visual flight weather conditions and there is no reason to believe the aircraft were not being operated in accordance with cloud separation criteria of visual flight rules. Under these conditions and according to these rules the vast portion of flying today is being conducted. Accordingly, the present means for avoiding collision rests with the pilot to see and avoid other aircraft.

Extensive study of most collision accidents has shown that there was an opportunity, of varying degree, for the pilot or pilots to see the conflicting aircraft in sufficient time for them to take evasive maneuvers to avoid the accident. In many of these accidents where there was survival, however, testimony of the pilots was that they were maintaining a careful lookout but despite it they did not see the other aircraft in time to avoid it or that they did not see it at all.

Collision studies, including controlled flight tests, have pointed out that seeing other aircraft in flight is difficult. The degree of such difficulty is variable with numerous tangible and intangible factors affecting it. The first tangible factor is the angular limits of cockpit vision, or the vision afforded by cockpit structure and design only.

The second tangible factor is visual range or the distance that an object can be seen. Many conditions and circumstances enter into this factor and are variable. Some of these are color of the object, its background, and the contrast between them. Others are mass of the object, its angular size and shape, and the atmospheric condition of visibility. The latter may also include altitude effect and cloud obstruction.

A third group of factors is physiological or human and many of these are intangible, depending on the individual's physical condition, degree of fatigue, and training. The human eye will best see an object when it is within the sensitive or focal field of vision, which is two to three degrees. An object may be seen through the peripheral portion of vision or the area of several degrees outside of the focal field. The number of degrees is dependent upon motion

and/or the aforementioned factors providing sufficient stimuli. It may be noted that aircraft converging on constant, unvarying collision courses provide no relative motion when viewed from the aircraft. Searching for aircraft within the visual limits of cockpit visibility requires scanning through those limits. This requires time, the amount being allied to the physiological factors and the adequacy depending on all considerations, including closure speed.

Allied to the element of opportunity it is important to recognize that the operation of a modern aircraft requires regular and frequent attention of the pilot or pilots to duties within the cockpit. Attention to instrumentation, both operational and navigational, is required during all phases of flight, as well as computations and records pertaining to the progress and anticipated progress of the flight.

Many combinations of adverse factors, conditions, and circumstances can result in a limited opportunity to see another aircraft. On the other hand the opportunity to see another aircraft may be good. Here the factors act to a good and reasonable opportunity for the vigilant pilot and in this regard the Board expects pilots to maintain the highest degree of vigilance.

It is recognized that the basic means for traffic separation in VFR conditions is presently the "see and be seen" philosophy. This concept has existed as a matter of necessity, with its known limitations, and will continue until there are sufficient technological advances to provide additional assistance to the pilot for collision avoidance. The progress of aviation is moving rapidly toward higher altitudes and greater speeds, with traffic in increasing density. Fully aware of this and its effect, the Board is lending its support to industry, other governmental agencies, and interested persons to find and develop methods, means, and devices which will assist the concept of visual separation.

Knowing full well that insufficient evidence would preclude determining with positive results the existing opportunities for the subject crews to see the conflicting aircraft, the Board nevertheless conducted an exhaustive analysis. This was done to present all information possible from the available evidence. The analysis was successful in this objective and disclosed much which the Board believes will assist its principal goal of greater safety in aviation.

Since the attitudes of the aircraft relative to the ground and their probable flight paths prior to collision are so closely interrelated, they can be treated together. A determination of these is imperative relative to the opportunity for the pilots to have seen the conflicting aircraft.

As indicated, correlation of the physical damage relates one aircraft with respect to the other and not with respect to the ground. Obviously, the physical orientation is valid only at the instant of impact. Because of this, and in the absence of eyewitnesses, it is not known whether one or both aircraft were rolled, pitched, or yawed relative to the ground. Without a known orientation of at least one of the aircraft with respect

to the ground, an analysis cannot determine a single flight path of the aircraft prior to the collision, nor is it possible to establish the flight paths by other known factors in this accident. It is therefore necessary to evaluate the objective on the basis of several flight path combinations, knowing that only one existed. Generally, however, the possibilities may be narrowed into two broad categories with variations. The possibilities may also be limited by the known orientation of the aircraft to each other at the instant of impact, which precludes certain other relative attitudes between the aircraft.

The first category assumes that there was no evasive action prior to collision and that one or both aircraft were turning within the limits afforded by the known collision orientation. This category accepts as reasonable that both aircraft were being flown commensurate with their performance for the en route phase of flight. Analytical studies recognized the variations to this category but found that three limit considerations seem to cover the infinite number with respect to the pilots' visual opportunities. Two of these are that either aircraft was turning while the other flew straight and level to collision; the third is that both were turning prior to the accident.

The second category of possibility is based on the assumption that there was an evasive action initiated by one or both flights but that it came too late to avoid the accident. Again, it is reasonable to believe the evasive action was limited to the known orientation and that the aircraft were being flown according to the normal performance for the en route phase of flight. The evasive action was also limited to aileron-elevator type maneuvers. Although rudder displacement was studied and evaluated, the aileron-elevator action appeared to be more consistent with the preponderance of all evidence; however, this was not entirely conclusive. Even accepting this limit there are variations, but these can be narrowed by a limit consideration. This is possible because maneuver characteristics of both aircraft showed that an evasive action without sufficient time to avoid the collision would not appreciably alter the flight path of either aircraft from flight paths which presumed there was no evasive action. It must be noted, however, that relative attitudes of the aircraft would be changed. Accordingly, the studies under the second category relating to the visual opportunities of the crews are not appreciably altered from the situation where both aircraft were approaching one another in straight and level flight at the angle between the longitudinal axes shown to have existed at the initial impact, 25 degrees.

It is known that several cloud buildups existed in the immediate area of the collision and their heights extended well above the cruising altitudes of both flights. Although it is unknown, it is entirely possible that the aircraft may have been flown so that one was on each side of a buildup shortly before collision. The effect of this would, of course, preclude the crews from seeing the other aircraft during the time the cloud or clouds were between them. Clouds would also require course deviation in certain situations. They would also seriously limit the time for pilots to see the conflicting aircraft, the amount depending on the size and shape of the clouds, the lateral distance maintained by the flights from them, and the distance of the clouds from the

collision point. Thus, a cloud positioned close to the collision point would limit the time opportunity as would one which was narrow or elongated. The intervening cloud factor appears to be a possibility and therefore was a necessary consideration in the visual opportunity study. To this end several representative cloud sizes and shapes were selected and introduced in the analytical study. The study also included the consideration which presumed that clouds would not have been a factor. The study accepted as the limit of visual range a distance of five to six statute miles and assumed that the aircraft passed the cloud formation at a horizontal distance of 2,000 feet and that they were at the same altitude.

The results of this analysis were then applied to the individual crew members from their respective cockpit positions. This was accomplished in the form of windshield displays, thereby incorporating the several situations with the angular limits of cockpit vision. Attachment 3 reflects the results as applied in this manner.

From the display it is apparent that the L-1049 was within the angular limits of the DC-7 window area from the captain's seat during all the flight path situations. In the situation of no intervening clouds, motion would be involved in three of the four situations. Windshield formers would block the captain's view for varying portions of the time opportunity. The time opportunity with no clouds was 50 to 120 seconds according to the situation being considered. The worst cloud situation could reduce the time opportunity to as low as 12 seconds.

With respect to the DC-7 first officer's position, the L-1049 was within the angular limits of the DC-7 window area during two of the limit considerations and during the early part of the other two. In the "no cloud" factor situations the L-1049 would have been near maximum visual range in two conditions, without relative motion in one, and with relative motion in another. Time opportunity without intervening clouds and with both aircraft straight and level was 120 seconds. For the other three considerations, including the intervening cloud condition, the opportunity varied from 12 seconds to 50 seconds.

In only one of the conditions does it appear that the L-1049 captain could have seen the DC-7 from his seat; in this the time opportunity was for a period of up to 40 seconds with no intervening clouds. In the other three conditions, according to the study, his opportunity was precluded by the limits of cockpit structure or because the DC-7 was beyond visual range.

The study indicates that without the intervening cloud condition the DC-7 was within visual range and within the angular limits of cockpit vision from the L-1049 copilot's seat during three of the four flight path situations. Then the time opportunity varied from 50 to 120 seconds, according to the situation. Two of the displays reveal relative motion. Again, in the worst cloud situation his time opportunity was as low as 12 seconds.

Analysis of the various possible flight path variations relative to cockpit angular limits of vision has shown that one or both pilots of one

aircraft could have been precluded from seeing the conflicting aircraft during critical periods. The study must also recognize the possible effect if one crew member was occupied with cockpit duties and he alone had the visual opportunity during this time.

The Board has shown the existence of cumulus-type clouds in the accident area. It has shown that these clouds may not have been an intervening factor between the flight paths of the aircraft. Here the time opportunities for the pilots to effect visual separation were good. In this situation, despite the possible flight path variations, and in consideration of the aforementioned factors controlling visual ability of the pilots, the Board is of the opinion that the range of opportunities was adequate. If this situation existed, the Board believes the pilots should have seen and avoided the other's aircraft.

On the other hand, evidence has shown that during other of the possibilities the pilots' opportunity to effect visual separation could have been seriously impaired. Analysis has shown how clouds, if positioned between the flights at a critical time, could have reduced the time opportunity for collision avoidance to less than the minimum of 15 or more seconds necessary for scanning, pilot reaction, and airplane response.

The Board has carefully studied and arduously evaluated all the available evidence surrounding this accident. It has learned all that existing methods of investigation and evaluation enabled it to do. This was done without the assistance of survivors or eyewitnesses whose testimony is considered imperative to a complete knowledge and to single conclusions in the collision-type accident. Because of the lack of this vital information and when all factors, including intervening clouds, cockpit visual limitations, cockpit duties, the several flight path variations, the time opportunities, and the physiological limits to human vision are considered, the Board concludes there is not enough evidence to determine whether or not there was sufficient opportunity for the pilots to avoid the collision.

Findings

On the basis of all available evidence the Board finds that:

1. The companies, the aircraft, and flight crews were properly certificated.

2. Preparation for both flights was complete and routine.

3. The flights were properly dispatched on IFR flight plans, over accepted high-altitude direct routes.

4. Approaching Daggett, TWA 2 requested its company radio to obtain 21,000 feet as an assigned altitude, or 1,000 on top.

5. Company radio requested 21,000 feet IFR from ARTC. This was denied by ARTC. Request was then made for 1,000 on top. This was approved and clearance issued. The flight climbed to and proceeded at 21,000 feet.

6. As an explanation for the denial of 21,000 feet, TWA 2 was furnished pertinent information on UAL 718.

7. The last position report by each flight indicated it was at that time at 21,000, estimating the Painted Desert line of position at 1031.

8. The Salt Lake controller possessed both position reports at approximately 1013, at which time both flights were in uncontrolled airspace.

9. Traffic control services are not provided in the uncontrolled airspace and according to existing Air Traffic Control policies and procedures the Salt Lake controller was not required to issue traffic information; none was issued voluntarily.

10. A general overcast with some breaks existed at 15,000 feet in the Grand Canyon area.

11. Several cumulus buildups extending above flight level existed; one was nearly over Grand Canyon Village and others were north and northeast in the area of the collision.

12. The collision occurred at approximately 1031 in visual flight rule weather conditions at about 21,000 feet.

13. The collision in space was above a position a short distance west of the TWA wreckage area, 17 miles west of or approximately 3-1/2 minutes' flying time from the Painted Desert line of position.

14. Under visual flight rule weather conditions it is the pilot's responsibility to maintain separation from other aircraft.

15. At impact the aircraft relative to each other converged at an angle of about 25 degrees with the DC-7 to the right of the L-1049. The DC-7 was rolled about 20 degrees right wing down and pitched about 10 degrees nose down relative to the L-1049.

16. There was no evidence found to indicate that malfunction or failure of the aircraft or their components was a factor in the accident.

Probable Cause

The Board determines that the probable cause of this mid-air collision was that the pilots did not see each other in time to avoid the collision. It is not possible to determine why the pilots did not see each other, but the evidence suggests that it resulted from any one or a combination of the following factors: Intervening clouds reducing time for visual separation, visual limitations due to cockpit visibility, and preoccupation with normal cockpit duties, preoccupation with matters unrelated to cockpit duties such as attempting to provide the passengers with a more scenic view of the Grand Canyon area, physiological limits to human vision reducing the time opportunity to see and avoid the other aircraft, or insufficiency of en route air