SA-403 File 1-0003

AIRCRAFT ACCIDENT REPORT

Adopted: June 19, 1969

BRANIFF AIRWAYS, INC.

LOCKHEED L-188, N9707C

NEAR DAWSON, TEXAS

MAY 3, 1968

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON D.C. 20591

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SYNOPSIS

A Braniff Airways, Inc., Lockheed L-188, N9707C, operating as night 352 between Houston and Dallas, Texas, crashed approximately 1 mile east of Dawson, Texas, about 1648 c.d.t., May 3, 1968. The 80 passengers and 5 crewmembers aboard the aircraft died in the accident, and the aircraft was destroyed.

Following a takeoff from Houston at 1611, night 352 was approaching an area of severe thunderstorms astride the airway from Houston to Dallas at an altitude of 20,000 feet. At 1636:50, the crew requested a descent to 15,000 feet and permission to deviate to the west of their intended flightpath. The Air Route Traffic Control Center radar controller advised the crew that other aircraft were deviating to the east but Flight 352 stated that on their radar, it looked all right to the west. Their request for deviation was approved and at 1639:12.5, they were cleared to descend to 14,000 feet. At 1642:20.5, they were advised that another Braniff flight was crossing in front of and below them, and was deviating to the east en route to Dallas. At 1644:21, night 352 was cleared to descend to and maintain 5,000 feet, at their request, and approximately 1 minute later the crew asked the controller if he had any reports of hail in the area in which they were flying. The controller replied "no" and again advised the crew that other flights were deviating to the east. At 1647:23, the flight requested permission to make a 180" turn and was cleared to make the turn in either direction. The crew acknowledged this clearance at 1647:35, and there were no further recorded transmissions from them.

Witnesses observed what appeared to be an explosion in the sky and saw the aircraft fall to the ground in flames. The wreckage of the aircraft was found scattered along a line oriented generally south-southeast/north-northwest. The wreckage area was approximately 3 miles long and generally 2,000 feet wide. Major components, including the right wing in two major sections, the empennage, the flight controls, and the two left engines were recovered separately from the major portion of the aircraft.

Pilots flying in the area of the accident, and ground witnesses in and around Dawson, reported that there was a considerable amount of thunderstorm activity in the area where the accident occurred, with numerous reports of lightning, hail, turbulence, and high winds.

The Board determines that the probable cause of this accident was the stressing of the aircraft structure beyond its ultimate strength during an attempted recovery from an unusual attitude induced by turbulence associated with a thunderstorm. The operation in the turbulence resulted from a decision to penetrate an area of known severe weather.

1. INVESTIGATION

1.1 History of the Flight

Braniff Airways, Inc., Flight 352, was a regularly scheduled domestic passenger flight between Houston, Texas, and Memphis, Tennessee, with intermediate stops at Dallas, Texas, Tulsa, Oklahoma, and Fort Smith and Little Rock, Arkansas. The scheduled gate departure time was 1600 1/ and takeoff was scheduled for 1605.

The crew of Flight 352 filed an Instrument Flight Rules (IFR) flight plan requesting flight level 200 (FL 200) via Jet Route 87 to Dallas. The filed true airspeed was 330 knots and the estimated time en route was 52 minutes.

The flight left the gate on time but its takeoff was delayed until 1611 due to other traffic in the area. Flight 352 was cleared to Dallas as filed and reported level at FL 200 at 1630:40. At 1635:53, the first officer called the Houston Air Route Traffic Control Center (ARTCC) and said, ". . . A few miles up the road we'd like to deviate to the west, looks like there's something in front of us." The controller acknowledged this request and, because the flight was approaching the handoff point at which control would be transferred to the Fort Worth ARTCC, he passed the request for the deviation to that facility along with the handoff. While the handoff was being coordinated between the Centers, the crew of Flight 352 requested a descent clearance to 15,000 feet. This message was not heard by the Houston controller. At 1636:15, the Houston controller instructed Flight 352 to contact Fort Worth Center and advised the crew that their request for deviation had been relayed. At 1636:52, Flight 352 contacted Fort Worth Center and again requested a deviation to the west and a descent clearance to 15,000 feet. The Fort Worth Controller replied ". . . suggest deviation east of course, . . . the aircraft are deviating that, that way at the present time. . ." In reply, Flight 352 said, "Three fifty two does it look good (better) (.) On our scope here it looks like to the uh a little just a little bit to the west would do us real fine." The controller then approved the deviation to the west and advised the crew to stand by on their request for an altitude change. At 1639:12.5, Flight 352 was cleared to descend to and maintain 14,000 feet, and the crew reported leaving FL 200 shortly thereafter. At 1642:20.5, the

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1/ All times are central standard time expressed on the 24-hour clock unless otherwise noted.

controller advised Flight 352 that they had ". . . company traffic (Braniff Flight 154, an L-188) at ten o'clock, eight miles, northeast bound, at one three thousand. Waco altimeter is two niner seven *six* and he's deviating east of course." This transmission was acknowledged by Flight 352. At 1643:20, Flight 352 requested a lower altitude which was denied because of the company traffic which was then directly below them. At that time, the controller asked Flight 352 for their heading and was told that ". . . we're turning over to a heading of three forty degrees now." At approximately 1643, Flight 352 requested a descent to a lower altitude and was cleared to descend to and maintain 5,000 feet at 1644:21. At 1646:10, the controller asked Flight 352 "Eraniff three fifty two do you indicate the area you're *going* into there now as being . . . fairly clear or do you see openings through it?" Flight 352 replied ". . . it's not clear . . . but we think we see an opening through it." At 1646:32.5, Flight 352 asked the controller if he had *any* reports of hail "in this area." The controller replied "No, you're the closest one that's ever come to it yet . . . I haven't been able to, anybody to, well I haven't tried really to get anybody to go through it, they've all deviated around to the east." At 1647:20, Flight 352 requested permission to make a 180° turn and the controller approved the turn "right or left." The last recorded transmission from the flight acknowledged this clearance at 1647:35.

The Fort Worth Center radar being used in the control Flight 352 was operating with circular polarization on. This feature is designed to lessen the interference caused by precipitation echoes and thus to assist the controller in observing radar targets of aircraft in areas of precipitation. Despite the use of circular polarization, there was an area of precipitation echoes displayed on the radarscope which was about 10 miles wide, measured from north to south, and forming a line which extended westerly from north of Waco, Texas, and northeasterly from Waco to a point approximately 4 or 5 miles east of the intended flightpath of Flight 372. That portion of the echo northeast of Waco was approximately 2.5 times wider on its north-south axis than the echo to the west. The southern boundary of this echo was just north of Waco at the time of the accident. There was no apparent difference in intensity of the echo from one portion to another. The echo was so bright that it was not possible to see aircraft radar targets, either primary or secondary, through it. There were no echoes visible farther east on the radarscope. When the controller was unable to'establish radio contact with Flight 352, he turned off the normal radar gain in an effort to detect the transponder return from the aircraft. This action was accomplished within 1 minute of the determination of a loss of radar contact.

There was no evidence of any radar target in the area where the precipitation echo had appeared on the radarscope. The radar used for the control of air traffic is not able to detect the height of precipitation echoes even when they are visible on the radarscope.

A review of the transcription of the cockpit voice recorder tape indicates the crew of night 352 first became aware of the obstacle presented by the storm when it was about 60 miles away from them. At 1635, a comment appears on the tape from the second officer "What's that, (about) * 2/ sixty miles in front of us?" The captain replied "and it looks like a pretty good one, too --- looks like we'd better deviate to the west." They then requested the deviations and altitudes previously described.

At 1637:23, the captain said, ". . . it looks like there's a hole up ahead to me." And the first officer replied "Yeah." At 1637:46, the captain made an announcement to the passengers advising them of the latest Dallas weather, the expected time of arrival at Dallas, on schedule at 1658, and that there was a "little line of thundershowers" ahead and the flight would deviate a little bit to the west for a smoother, more comfortable ride.

At 1641:07, the captain made another announcement to the passengers advising them that he was turning on the "seat belt" and "no smoking" signs "just in the event it's a little choppy in the area." He stated that his radar was working and he was going to be able to "go well under and to the west of all the thundershowers, but they will be visible to you to the right. . . ." At 1641:42, the captain said "I guess I can go under." At 1645:16, the captain instructed the flight engineer to turn on the engine heat temporarily, "at least on number one, till we get above twelve degrees or a clear area." At approximately 1646:30, the captain instructed the first officer to ask the controller if he had any reports of hail, which the first officer did at 1646:32. The controller replied "No, you're the closest one that's ever come to it yet, . . . I haven't been able to, anybody to, well I haven't tried really to get anybody to go through it, they've all deviated around to the east." Following this transmission, the captain advised the first officer, "No, don't talk to him too much. I'm hearing his conversation on this. He's trying to get us to admit (we're makin) (we'd made the) (we made a)3/ big mistake coming through here." The first officer stated

2/ Unintelligible word or phrase.

3/ The words enclosed in parentheses are garbled and subject to one of the three indicated interpretations.

shortly after that, ". . . it looks worse to me over there." This statement was followed by the sound of the landing gear warning horn and the statement of the captain "Let it ring." The captain then said, at 1647:20, "Let's make a one eighty" and the first officer requested permission to make the turn, from the center, 3 seconds later. The turn was approved "right or left" at 1647:26.5. At 1647:29, a sound similar to hail or heavy rain was recorded and, at 1647:30.5, the first officer transmitted "three fifty-two." One-half second later the captain said, "Let me know when we come back around there to reverse heading for rollout." There was no recorded reply to that instruction. At 1647:35.2, the first officer said "three forty," and immediately afterward the sound of a landing gear warning horn was heard and the captain said "Right." At 1647:41.3, the sound of a fire warning bell was heard and continued until the end of the recording. At 1647:41.9, a sound appeared that was described as being similar to breakup noise and, at 1647:42.4, there was a sound induced onto the recorder tape by the changing of the electrical power for the recorder. The recording ended at 1647:44.1.

Approximately 75 persons were contacted as possible ground witnesses to the accident, and statements were obtained from 47 of them. Only one of the witnesses interviewed saw the aircraft involved in the accident turning. Nearly all the observations that could be correlated with Flight 352 indicated that the aircraft was in straight and level flight. One witness stated that he saw the aircraft in a turn to the right, ". . . It had made almost a half turn. Then I saw a big red light and a sudden echo sound (sic). . . ." He then saw the burning wreckage fall to the ground.

Several of the witnesses reported seeing a stroke of lightning followed by an explosion and a falling aircraft on fire or a ball of fire falling to the ground. While some of these witnesses stated that the lightning struck the aircraft, others stated that it passed close to, or in front of, the aircraft. However, they all stated that the lightning stroke was immediately followed by the explosion and fire.

The witnesses in and around Dawson reported that it was either raining or hailing, or both, with high winds and lightning at the time of the accident. The witnesses described the clouds as being dark, black, green, or purple, and some of them noted a rolling or boiling motion in the leading edge of the clouds.

Some witnesses said the aircraft came out of clouds and was approaching another cloud when it exploded. Most of the persons interviewed did not see the aircraft but did observe the burning wreckage falling. A number of the witnesses noted that the flaming wreckage fell through lower clouds, but witnesses farther away were able to see the aircraft above the lower cloud and their observations of the fall of the wreckage was partially obscured as it fell through lower clouds.

The main portion of the wreckage was found in gently rolling terrain approximately one-half mile east of Dawson at an elevation of approximately 456 feet m.s.l. -- (31° 53' 55"N -- 96" 41' 50"W). The accident occurred at 1648 during daylight.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	5	80	0
Nonfatal	0	0	0
None	0	0	

1.3 Damage to Aircraft

The aircraft was destroyed by in-flight breakup, in-flight fire, impact, and post impact fire.

1.4 Other Damage

Farm buildings destroyed.

1.5 Crew Information

All crewmembers were properly certificated and qualified for their positions. (For details see Appendix A.)

1.6 Aircraft Information

The aircraft was properly certificated and the records indicate that it was maintained in accordance with existing regulations and directives. The records also indicate that the aircraft was airworthy on its departure from Houston. The weight and balance was within limits at takeoff from Houston and was calculated to be within limits at the time of the accident. The aircraft was serviced with a total of 18,000 pounds of jet fuel at Houston. (For details see Appendix B.)

1.7 Meteorological Information

The weather in the accident area at the time of the accident was characterized by considerable thunderstorm activity associated. with a pre-frontal squall line. Thunderstorms were observed and reported from Waco, Texas, southwest of the accident site, to Corsicana, Texas, northeast of the accident site. The 1600 surface weather chart prepared by the National Meteorological Center showed a cold front extending southwestward from southern Illinois to west-central Texas, and a pre-frontal squall line extending southwestward from near Memphis, Tennessee, to about 65 miles southwest of Fort Worth, Texas.

The 1500 Waco surface weather observation reported in part ". . . line of cumulonimbus west to north horizon," and at 1600, ". . . line of cumulonimbus west-southwest to west to north, cumulus mammatus north." At 1635, Waco reported, in a Special observation, measured 3,500 feet broken clouds, high overcast, visibility 15 miles, thunderstorm, light rain showers, wind 310° 15 knots, altimeter 29.79 inches, thunderstorm west-northwest, thunderstorm moving southeast, frequent lightning cloud to ground and cloud to cloud, northwest to north. Waco is approximately 30 nautical miles southwest of the accident site.

Tyler, Texas, approximately 65 nautical miles east-northeast of the accident, first reported cumulonimbus north to northeast of their station at 1600. At 1700, they reported cumulonimbus northeast to east, lightning in clouds, and cloud to ground, northeast to east.

Dallas, approximately 62 nautical miles north of the accident, reported very light rain showers at 1600. At 1636, in a check observation, they reported large cumulonimbus north to northeast, dark south, cumulus mammatus northeast to southeast to southwest, with the pressure falling rapidly. Again, at 1700, they reported very large cumulonimbus northeast, and cumulus mammatus east to south to southwest.

Fort Worth, approximately 60 nautical miles north-northwest of the accident, reported towering cumulus south to southwest at 1500. At 1529, in a Special observation they reported a thunderstorm which began at 1527. This thunderstorm was over the station moving east. There were also rain showers of unknown intensity west of the station. At 1600, they still reported a thunderstorm overhead moving east, moderate rain showers which began at 1531, and occasional lightning, cloud to ground, north-northwest of the station. In a Special observation at 1638, they reported the thunderstorm had ended at 1636 and there were cumulonimbus northeast to southeast of the station.

Radar weather observations were made of the area including the accident site by five radar weather observation stations, including Fort Worth, Waco, Galveston, Bergstrom Air Force Ease and College Station, Texas. Radarscope photographs were made at Fort Worth, Galveston, and College Station. These stations are located so as to provide radar weather observations of the' accident site from four different directions. At 1645, Waco was at the southern boundary of a broken to solid area of thunderstorm activity.

The Fort Worth 1658 radar weather observation was in part: a broken area of echoes containing thunderstorms producing heavy rain showers, with no change in intensity noted during the preceding hour. This area was east of the intended flightpath of the aircraft, but another broken area of echoes containing thunderstoms producing heavy rain showers, with no change in intensity during the past hour, lay astride the intended flightpath of Flight 352. There was a clear area approximately 60 nautical miles wide between these two areas. The maximum top of detectable moisture in the area across the airway (J-87) was 45,000 feet m.s.l., and the area was moving southeast at approximately 12 knots.

The Waco 1645 radar weather observation, in part, reported a broken to solid area of echoes containing thunderstorms producing moderate rain showers, with no change in intensity in the preceding hour. This area overlapped the area astride J-87 reported by Fort Worth.

Galveston reported, in part, at 1645, a scattered area of echoes containing thunderstorms producing rain showers of unknown intensity, with cells 15 miles in diameter moving from 270° at 20 knots. This area included the same areas previously described but was being viewed from a position approximately 180 nautical miles southeast of the accident site.

Pertinent pilot reports summarized at 1530 included reports of hail and a thunderstorm approximately 60 nautical miles northeast of the accident site, and a thunderstorm 30 miles north of Waco was reported to be 40 nautical miles on its east-west axis and 25 miles wide on the north-south axis. In the 1620 summary, there was a report, timed at 1543, of marble-sized hail at 2,500 feet 5 miles northwest of Fort Worth and moderate rain showers

10 miles wide over Dallas at 1555.

The Fort Worth 1330 radiosonde ascent below 20,000 feet m.s.l., showed absolutely unstable air to near 2,500 feet, conditionally unstable air from 2,500 to 4,400 feet, stable air from 4,400 to 7,400 feet, conditionally unstable air from 7,400 to 14,300 feet, stable air from 14,300 to 17,000 feet with conditionally unstable air above 17,000 feet. The air was relatively moist below 4,400 feet and generally dry above that altitude. The freezing level was near 11,900 feet.

The Aviation Terminal Forecast issued at 1145, and valid from 1200 to 0000 was in part as follows: Dallas and Fort Worth 1200-1700, 3,000 feet scattered clouds ceiling 8,000 feet broken clouds, 30,000 feet overcast, surface wind 220° at 13 knots and gusty, occasional ceilings of 2,000 feet overcast, visibility 4 miles in thunderstorm, and light rain showers in the vicinity after 1400. After 1700 until 2000, the ceiling was forecast to be 3,000 feet broken, 10,000 feet broken, visibility 7 miles, variable to 1,500 feet broken, 4,000 feet overcast with 3 miles visibility in thunderstorm and moderate rain showers.

The Weather Bureau Aviation Area Forecast pertinent to the area of the accident was issued by the Forecast Center at Fort Worth at 1345, valid from 1400-0200 and was in part as follows: Northwestern, north-central, northeastern Texas, and Oklahoma: ". . . Cold front at noon near Joplin-Fort Sill-Lubbock line moving southeastward about 15 knots . . . Along and about 140 miles southeast of the front generally 8,000-10,000 feet scattered variable to broken, . . . but scattered thunderstorms developing during afternoon with conditions locally ceiling 1500-3000 feet broken variable to overcast, visibility 2-5 miles, thunderstorms, heavy rain showers. Chance few severe thunderstoms with tops near 50,000 feet occasionally forming lines ahead of front and continuing throughout the night. Possible isolated tornadoes mainly north-central Texas and southeastern Oklahoma. . . ." Icing was forecast to be mixed moderate or greater in thunderstorms above the freezing level and turbulence was forecast to be moderate or greater 5,000 to 10,000 feet over northwestern Texas and western Oklahoma, and at all levels in the vicinity of thunderstorms and buildups.

An Aviation Severe Weather Watch Bulletin, Number 135, was issued by the National Severe Storms Forecast Center at Kansas City at 1213 which read in part as follows: ". . . Area Two.

Tornado Watch Valid 1400-2000. A. Along and 60 nautical miles either side of a line from 60 nautical miles west of Mineral Wells, Texas, to 60 nautical miles southeast of Fort Smith, Arkansas. B. Tornadoes, a few severe thunderstorms; hail, surface and aloft to 2 inches, extreme turbulence and surface wind gusts to 65 knots. Scattered cumulonimbus with maximum tops to 55,000 feet. C. Thunderstorms expected to intensify in this area during the afternoon with short instability lines moving eastward at 15 to 25 knots. General thunderstorms. Unstable air mass in the eastern portion of southwest Texas and south-central Texas expected to produce late afternoon and early evening heavy thunderstorms."

SIGMET Charley 1, issued by the Forecast Center at Fort Worth at 1520 valid from 1520 to 2000, was as follows: Over northeastern and north-central Texas and southeast portion of northwestern Texas at 1500 a line of thunderstorms ran from Texarkana to 40 miles south of Dallas to 40 miles southwest of Abilene, moving southeastward at 10 to 15 knots. A few severe thunderstorms with tops above 50,000 feet. This condition was expected to continue after 2000.

The Braniff Airways, Inc., Meteorology Department, issued a forecast at 1445 which read in part as follows: Significant weather; scattered to broken thunderstorms developing all along the cold front through Pennsylvania, Kentucky, Tennessee, Arkansas to Texas. Locally severe thunderstorms along or in advance of the dry line dew point front in Texas. Dry line east of Big Spring to west of Junction to west of Del Rio, Texas. Locally severe thunderstorms were forecast from 1800 until 0000 in the area bounded by McAlester, Oklahoma; Texarkana, Texas; Tyler, Texas; Austin, Texas; San Antonio, Texas; Junction, Brownwood, Abilene, Mineral Wells, Perrin, and back to McAlester. Moderate to severe turbulence was forecast in the vicinity of cells, locally extreme turbulence in larger cells. Hail up to 1-1/2 inches in diameter was forecast in the vicinity of the larger cells. Additionally, a jet level forecast issued by Braniff at 1210 valid May 3, 1968, 1300 to May 4, 0300 read in part: ". . . Some heavy thunderstorms expected over north-central Texas . . . Moderate or greater turbulence vicinity of all buildups any level. . . ." Finally, the Braniff forecast called for scattered thunderstorms and moderate rain showers in the vicinity of Dallas-Fort Worth, from 1600 to 1730.

The crew of Flight 352 was not briefed regarding the weather by any Weather Bureau or FAA personnel prior to their departure from Houston, and there is no record of any contact between the crew and the company dispatcher or weather office prior to their departure from Houston. Prior to the crew's departure from Dallas to Houston at 1240, the dispatcher discussed the weather along the route with the first officer. At that time, the dispatcher stated, there were no radar summary reports indicating any lines of thunderstorms south of Dallas, although there were some showers in the Dallas area.

Prior to their departure from Houston, the crew was provided with SIGMET Charley 1, the 1600 surface weather observations, the 1045 Weather Bureau Terminal Forecasts, the Braniff 1110 Jet Level Forecasts, the Braniff Terminal Forecast, Severe Weather Watch Bulletin 135, and the 1530 terminal forecast. Additionally, the crew had available from the Braniff self-help briefing board all the Weather Bureau and Braniff weather data available at the time of their departure from the Houston terminal.

More than 25 statements were received from aircrews operating in the general area of the accident. The consensus of their statements was that the storm centered in this area was one to stay away from. Their description of color of the cloud ranged from pale green to dense black, and the tops were estimated to be between 26,000 to 40,000 feet. Most of the crews approaching Dallas from the south initially requested deviation to the west of course but were informed that most other crews were deviating to the east. Only two crews were known to have deviated west of course. The captain of Braniff Flight 154, operating from Austin to Dallas, stated that, as he approached Waco from the south, he could see a line of thunderstorms, both visually and on the airborne radar. He observed "two good breaks in the line west of Waco and the line of weather was heavy to the east of Waco." He requested permission to deviate to the west of Waco from a point about 30 miles south. He was advised by the Fort Worth controller to deviate to the east and he accepted that. advice about 1640 because his radar showed the line of storms ended about 70 miles east of Waco. The crews who operated east of the line of thunderstorms reported smooth flying conditions throughout their operation into Dallas.

The accident occurred in cloudy, daylight conditions.

1.8 Aids to Navigation

There were no reported difficulties with any navigational aids utilized for flight from Houston to Dallas. The flight was operated under radar control from departure until just before the accident. At the time of the accident, radar contact had been lost by the controller when the aircraft's primary and secondary targets disappeared in the weather return on his radarscope.

1.9 Communications

There were no reported discrepancies in the communications facilities and radio contact was maintained with the aircraft until just before the accident occurred.

1.10 Aerodrome and Ground Facilities

Not involved in this accident.

1.11 Flight Recorders

N9707C was equipped with a Lockheed Air Service Model 109CR flight data recorder and Fairchild Cockpit Voice Recorder (CVR) Model A100, both of which were recovered in the primary wreckage area.

The flight data recorder cassette was mechanically damaged but had not sustained any fire damage. The flight record medium was torn and distorted, and the portion which included the record of the last part of the flight was scratched and gouged. The medium was reconstructed and some of it was found to be missing. Photographs were made of the reconstructed medium, and a readout was obtained from the liftoff point at Houston to the point where the recorder ceased to operate. These data were plotted on a graph and the following observations made: The reference lines were consistent with the current calibration; the styli operation appeared normal, and good time correlation was established between the parameters; all parameters were functioning and recording throughout the readout time period; and the data derived from the readout appear to be correct as sensed and recorded. The altitude data reported were based on a barometric pressure of 29.76 inches of mercury to convert the pressure altitude to mean sea level altitude for all altitudes below 18,000 feet. The other altitude data and parameters were uncorrected for instrument and position error, and were reported as indicated values.

The CVR was recovered in a mechanically damaged condition but there was no evidence of any fire damage. The stainless steel container and the tape transport mechanism were undamaged. The unit had ceased to function due to a loss of electrical power.

A review of the flight data recorder readout shows that the flight was without remarkable excursions of any traces until approximately 36 minutes after takeoff (1647). At that time there was an increase of both frequency and amplitude of excursions of the "g" trace and some sharp, small changes in the heading indication. The excursions of the "g" trace continue to increase in amplitude until they reach a maximum of 4.3 positive "g" at 1647:41.9. One other major spike in the "g" trace, of 3.8 positive "g", occurred at 1647:37. The maximum excursion of negative "g" occurred at 1647:23 when there was an indication of 0.9 negative "g". At 1646:56, the airspeed trace, which had been showing a gradual decrease from 230 knots to 192 knots, began to increase to a value of 216 knots. It then' decreased approximately 10 knots at 1647:21, leveled off for about 10 seconds, and then increased abruptly to approximately 360 knots over a time period of approximately 8 seconds.

The heading trace was without remarkable appearance until time 1647:21, at which time the heading indicated a turn to the right from a heading of about 350° to 184° at 1647:40.5. The trace then went to 180°, back to 200" and back to 182" in 4 seconds. From that point, at time 1647:44, the trace indicated a turn to 330° and left the appearance of reverse movement of the styli with relation to time.

Testimony of a NASA witness indicated that there are errors in the gyro compass system that are a function of bank angle, pitch angle, and gyro axis orientation. These errors can become very large at high bank angles. He stated that the differences between the computed headings and the indicated headings, in this case, fell within the magnitude of these demonstrated errors. He concluded, therefore, that at any bank angle beyond 70°, unless pitch angle and gyro axis were very well known, the heading became indeterminative from the recorded data.

At a bank angle of 45°, the error would be relatively insignificant. At 60° of bank, the maximum error would be about 25° and at 90° of bank the error could be as much as 90°. As the aircraft turns at these higher bank angles, the heading error will increase from zero to a maximum value and then reverse and go to a maximum value in the opposite direction. This cycle will repeat itself as the aircraft passes through each quadrant of a turn. These errors will disappear as the aircraft tilts back to level.

The altitude trace leveled off at approximately 9,700 feet at 1647:04, held near that altitude for about 14 seconds, indicated an increase to approximately 10,000 feet, then decreased to an indicated altitude of approximately 4,500 feet, at which point the trace disappeared. This occurred at 1647:46. In this connection, the altitude of the terrain in the accident area was approximately 450 feet m.s.l.

The CVR apparently functioned normally throughout the flight, and pertinent portions of the recorded data were reported in preceding parts of this report.

1.12 Wreckage

The right wing, empennage and parts of the aft fuselage, the left-hand engines, and control surfaces all separated in flight. These parts were found scattered along a wreckage path which extended generally south-southeast for nearly 3 miles from the main impact site. The fuselage and left wing struck the ground in a nose-low, right wing stub down attitude while traveling backward along a line of 228°.

The right wing was fractured in two places, just outboard of the fuselage and just outboard of the No. 4 engine. Both fractures were bending failures in a positive, or wing-tip upward direction, and both showed evidence of wing leading edge up torsion. There was no evidence found in the intact left wing which indicated overstress compared with that observed in the right wing.

Both the right horizontal stabilizer and the vertical stabilizer failed in bending in a counterclockwise direction as viewed from the rear of the aircraft. The left horizontal stabilizer separated from the fuselage, with portions of the aft fuselage and the stub end of the right horizontal stabilizer still attached to the fuselage segment.

All fracture surfaces examined were typical of those caused by overloads. No evidence of fatigue or in-flight explosion was observed. There was no evidence of flutter observed on any major component or on the control surfaces.

No evidence was observed, on any part of the structure examined, which would indicate that the aircraft had been recently struck by lightning, nor was there any evidence of hail damage. There was no evidence of a fire prior to the in-flight structural failure and no evidence of an explosion occurring in the structure.

The first observed evidence of ground contact of the main body of the aircraft was located at an elevation of 456 feet m.s.l. There was a shallow crater at this point and another larger crater approximately 30 feet away on a true heading of 228°. Various parts of the cockpit and forward fuselage were located in and around the first crater, while parts of the broken end of the right wing and wing center section were found in the second crater. The outboard end of the left wing was found facing toward the direction from which the aircraft had come, with a tree wedged into the trailing edge.

The edge of the first crater was chosen as a starting point to measure the wreckage distribution and designated Station 0/00, and a survey base line was extended through the approximate center of the location of the parts for a distance of 16,000 feet (Station 16/00). This line measured approximately 129° to Station 2/70, then turned right to 162° to Station 11/50, and then left to approximately 147° to Station 16/00. With few exceptions, most of the separated parts were found within 500 to 800 feet on either side of this base line.

The Nos. 1 and 2 engines and their respective propellers, separated from the engines, were found within 800 feet of Station 0/00.

The main section of the separated right wing, including Nos. 3 and 4 engines and the No. 4 propeller were located 1,750 feet east of Station 0/00, and most of the pieces of the right wing control surfaces were located along and slightly south of a line between this section of wing and Station 0/00.

The separated outboard end of the right wing was located 280 feet east of Station 2/60. Most of the left wing control surface parts and left engine cowl parts were located west of the base line from Stations 1/00 to 4/00. The left horizontal stabilizer was located 80 feet east of the base line near Station 2/90, the vertical stabilizer and rudder were 340 feet west of the base line near Station 3/20, and the right horizontal stabilizer 320 feet east near Station 4/90. Most of the pieces of the right wing planks were found scattered along, and generally east of, the base line from Station 3/00 to 9/00. The parts recovered behind Station 9/00 were generally light or of relatively low density.

The right wing was recovered in two large, complete sections and in many small pieces of plank, beam web, and rib structure. The outboard end was intact from the tip assembly inboard to Wing Station (WS) 398 along the front beam and leading edge, and inboard to WS 516 at the trailing edge. This section sustained relatively little mechanical damage except for punctures of the leading edge and inward and upward crushing of the tip assembly. There was evidence of ground fire in the area where the tip assembly was recovered. The upper planks outboard of the fracture area were partially melted and buckled with solidified metal drippings hanging vertically under the wing as it lay in the field.

The other large section contained Nos. 3 and 4 engines, the No. 4 propeller, engine mounts, nacelles, and a section of trailing edge flap. The outer extremities of this wing section were WS 122 and 448. The leading edge was attached to the front beam web between the nacelles but had moved forward and upward in relation to the wing in its normal position. The leading edge lower surface was separated from the wing box structure just forward of riser No. 1 with a smooth 45° tensile shear fracture surface displayed between WS 249 and 323. The steel fasteners attaching the front lip of plank No. 1 to the front beam cap were tipped spanwise, with the inboard edges depressed and the outboard edges raised.

This section of wing was recovered from an area where ground fire had occurred. The wing section exhibited general fire damage, with the heaviest damage occurring between the nacelles and in the wheel well area. All ribs inside the box section between the nacelles were broken or partially consumed by fire, and the upper skin had partially melted and subsided to the ground. In the wheel well area, the front beam and parts of both upper and lower surfaces were partially consumed by fire, and little but solidified slag remained of some parts.

The pieces of wing plank which separated from the upper and lower surfaces varied considerably in size. These varied from long, narrow sections with little apparent deformation found at the outboard fracture to much smaller pieces near the inboard fracture. The pieces of upper plank from WS 65 outboard to WS 155 generally consisted of skin only; nearly all of the risers had been separated. These latter pieces exhibit more deformation than was apparent elsewhere in the planks, particularly in the buckling of the pieces along WS 101.

Only fragments were recovered of the portion of the front beam between WS 65 and the outboard side of the No. 3 nacelle. In all cases where such fragments of beam were found, they consisted only of web or of the web and the vertical tangs of the beam caps. Two small pieces, one of which remained attached to a section of center-wing attach structure at WS 65, were recovered from the main impact site and were free of fire damage.

The front beam was burned away at WS 205, fractured diagonally upward and inboard at WS 235, and was separated from the box section outboard to WS 329. The upper half of the beam was burned away from WS 275 into the No. 4 nacelle area, from which point it was continuous out to a ragged, but generally vertical, fracture at WS 398. This fracture showed evidence of a tension-twisting rupture at the lower surface and a compression-twisting rupture of the upper surface. The direction of twisting was counterclockwise when viewed from the outboard end of the wing.

Nearly all of the rear beam was recovered except for a section in the area of WS 65 to 100. Fractures in the area of WS 101 mated with a longer section which extended outboard to WS 141. The edges of the vertical fractures on both ends of this section were bent aft. These pieces were unsooted and unburned. The rear beam section which remained in the intact main wing section mated with the fracture at WS 141 and continued outboard to WS 397. The portion of the rear beam from WS 397 to 516 separated from the wing box structure and from most of the trailing edge structure. The fracture at the inboard end was consistent with a tensile failure in the upper part of the beam and an aft bending failure near the lower surface. The rupture along the lower edge of the beam showed evidence of bending in a direction which would increase the angle between the lower surface and the beam.

A tearing-type of fracture originated approximately at WS 515 between the beam and the upper skin. The beam was bent forward from WS 495 to 516. The outboard rupture had the appearance of a tensile failure.

All available, identifiable wing plank material from the right wing was collected and mocked up. (See Appendix C.) The most extensive fragmentation of the upper wing panel occurred between WS 65 and 155. When the pieces from this area were assembled in the mockup, little material was identified from the Nos. 1 and 2 planks. Several square feet of upper wing plank fragments, believed to have been from the WS 65 to 101 area, were not positively identified and could not be placed in the mockup. The mockup established a pattern of compression buckling, with evidence of a chordwise buckle extending along WS 101 from the rear beam forward into the No. 3 plank. Nearly all of the risers had separated from the planking in this area and considerable deformation was apparent in the material along the edges of the 'fracture, with some of the tangs of material along either side of the rupture, bent upward and some downward.

A fracture in the upper planks ran roughly chordwise through planks Nos. 1 and 2 near WS 380, and chordwise near WS 397 back almost to the rear beam, at which point the aft plank fractured near WS 410. Part of the front and most of the rear extremities of the fracture mated with pieces recovered along the wreckage path. Nearly all of the outboard upper planking between this break and one near WS 499 was recovered in relatively long spanwise strips. The skin along the rupture at WS 380 to 397 was bent upward; however, the pieces were relatively flat and the contour noted approximated that of the original wing contour.

Although these pieces exhibited many longitudinal as well as transverse fractures, the diagonal rupture which was evident in the lower surface of this area was not apparent in the upper surface. The outboard fracture arced outboard and aft from the area of WS 482 at the front beam approximately to WS 500 at the rear of plank No. 2, then inboard to WS 482 at the rear of plank No. 3 and outboard to near WS 516 at.the rear beam. The pieces recovered from this area were free of fire damage and sooting. The upper surface outboard of this fracture on the outer panel was fire damaged near the fracture and had longitudinal splits in the forward planks.

Most of the lower wing planks were recovered and mocked-up. This mockup revealed an irregular chordwise break between WS 70 to 100 and a very irregular diagonal break in planks Nos. 5 to 8. This fracture originated near WS 83 at the forward edge of plank No. 4 and terminated near WS 122 at the rear beam, with a maximum outboard projection nearly to WS 137 along the juncture of planks Nos. 6 and 7.

The pieces of wing root inboard of the chordwise break, which were recovered in the main impact area, were neither burned nor sooted. The pieces nearer the forward part of the wing exhibited upward bending. Other portions of the skin inboard of the nacelle were burned or sooted when recovered in the area of the main wing section.

The failures in the forward half of the wing box section lower planking between WS 83 and 101 were primarily tension failures. Damage in the rear half of the rupture resembled the type of damage which would be produced by torsional loads, with the torsion operating counterclockwise when viewed from the wingtip.

The lower planks in the area between the nacelles were intact but buckled, with evidence of heat damage. The planks were fractured outboard of the No. 4 nacelle, with the break starting at

WS 398 along the front beam in plank No. 1, extending outboard to WS 448 in plank No. 3 and back inboard to WS 400 at the rear planks in this area. The projection of plank No. 3 was buckled downward across the fuel tank access door located just outboard of the nacelle. The fractured edges of the planks aft of this area were bent downward.

Several pieces, which apparently separated in flight and were recovered along the wreckage path, fitted the gap between the above-mentioned fracture and another diagonal fracture which extended aft and outboard from WS 398 at the front beam to WS 490 at the rear beam. Considerable deformation was apparent in the material along the edges of this fracture, especially along the outboard surfaces. These edges were generally bent upward with the bends parallel to the diagonal line from WS 398 at the front beam to WS 490 at the rear beam. The plank risers in this area also exhibited diagonal buckles. Many of the ends of the risers along the rear part of the fracture were split from the planks and bent forward and upward. The deformation of the structure in the area of this fracture was typical of damage which would be produced by 'bending the forward, outer tip of the wing upward and rearward.

All of the identifiable portions of the left wing recovered were found in the main impact area. The inboard end of the wing was extensively fragmented and pieces were found in the crater and scattered throughout the area. The portion of the wing outboard of the No. 1 nacelle was intact and relatively undamaged.

The area in which many of these components were recovered was an area where ground fire had occurred and fire damage was found on portions of some of the inboard ends of the wing planks, while other pieces were not burned or sooted. Spotty sooting was observed including some of fracture surfaces.

The outer part of the left wing from the outboard side of No. 1 nacelle to the tip was lying right side up, basically intact, with the control surfaces separated. The trailing edge was crushed by a tree approximately 4 feet from the tip, with the damage extending forward to the rear beam.

The mockup of the left wing was not as extensive as that for the right wing. However, the outboard panel was examined for evidence of overstress such as that sustained by the right wing. No evidence of overstress was found.

The right horizontal stabilizer was recovered in three main pieces, two of which had separated in flight. The third piece, the inboard aft corner, remained attached to the carry-through structure and the left horizontal stabilizer.

The outboard section of the stabilizer was generally intact from the tip to an upward bending fracture near the fuselage. The upper surface failure occurred along Horizontal Stabilizer Station (HSS) 42 from the rear beam forward to Fuselage Station (FS) 1193, then outboard to HSS 67 and forward to FS 1185. It then progressed outboard to HSS 80 and forward to the front beam, which failed at HSS 62. The beam was bent forward about 30° from HSS 80 to 62. The stabilizer lower surface failed in tension approximately along HSS 53.

The right stabilizer leading edge was crushed up and outboard from HSS 65 to 80 and was covered with soil. Just outboard of this crushed area was a smear of red paint similar in color to the red lettering on the vertical stabilizer.

The entire exterior surface, including the fracture surfaces, of the outboard section of the right stabilizer exhibited deposits of moderate oily soot, with some washing by fuel evident at the inboard end which had reduced the amount of soot in the washed areas. The strip of lower skin, which separated, exhibited lighter sooting on its exterior surface than that on the mating parts of the stabilizer and there was no soot on its inner surface.

Some of the jagged edges along the chordwise portion of the inboard fracture (HSS 32) were bent slightly upward. The inboard fracture of the front stabilizer beam occurred at Butt Line (BL) 24 Right (R) in the upper cap and at BL 35 R in the lower cap. The web failed through a row of attaching rivets in a repair and reinforcement plate spanning the area defined by the inter-section of the fuselage contour and the horizontal stabilizer front beam web. At the lower end; the failure was primarily tensile in nature and it progressed through the rivet holes in a zigzag fashion, characteristic of a tearing type of fracture. The beam upper cap had. a compression buckle at BL 5 L in the carrythrough structure.

The outboard fractures of the third piece of the right stabilizer mated with the other recovered pieces and shards of upper surface along the HSS 42 fracture were bent upward. Evidence of upward bending existed in the upper surface fracture from the front beam at HSS 32 aft to FS 1185, then outboard to HSS 42 and aft to the rear beam.

The left stabilizer was recovered intact, with the elevator in place, and, was still attached to parts of the aft fuselage bulkheads at FS 1167, 1185, 1203, and 1221. The upper surface and lower inspar surfaces were free of damage. The leading edge had chordwise rub marks from HSS 48 to 63. Another rub mark extended from HSS 74 to a 3-inch puncture at HSS 80, with a sharp-edged compression rub mark on the extreme leading edge extending outboard to HSS 95.

The vertical stabilizer was relatively intact. It had separated from the fuselage just below Vertical Stabilizer Station (VSS) 0 with a piece of fuselage skin from FS 1145 to 1185 and BL 15 L to 15 R still attached to the stabilizer skate angles. The forward edge (FS 1117) was crushed slightly aft at VSS 38. The right-hand skin had slight buckles at VSS 18 and 40 between FS 1117 and 1150. The right-hand side also exhibited scuff and score marks in the area from VSS 0 to 50 and FS 1125 to 1185 which extended up and aft through the red painted letters "Electra II". These marks made a 40° angle with the horizontal on the lower extremity and a 17° angle at the top. Farther aft, on the right-hand side at FS 1170, the leading edge of a 10-inch chordwise section of skin was separated from VSS 46 to 80 and the piece was curled outward 30°. The area just behind and below the tear was mangled with the skin and ribs crushed inward, twisted and torn. The rear-beam web was crushed inward at VSS 0 and 69. The FS 1185 right-hand attach stringer was separated in that same area. In addition to the damage sustained by the rear beam in this area, the beam had horizontal fractures at or near the rudder hinge brackets. There was evidence of an extreme rudder overtravel of approximately 80" to 90° to the right. The top of the inner section at VSS 173 had two sets of diametrically opposed, small darkened areas which were determined to have been caused by fretting.

The vertical stabilizer beam caps and attach stringers failed approximately flush with the fuselage bulkheads at FS 1150, 1167, and 1185. The right-hand rear-beam cap failed 10 inches above the FS 1203 bulkhead and the left-hand cap failed 7 inches above the bulkhead. The right-hand members failed in tension and the left-hand side failed in compression bending. The vertical stabilizer exhibited no evidence of fire damage or soot.

The flight control system was demolished by the in-flight breakup and the ground impact. Cables and mechanisms were found scattered along the wreckage path and throughout the main impact area.. Many parts, including cables, were consumed by fire in the main impact area. Because of the extensive damage, no determination of flight control system integrity could be made by examination. All control surface balance weights were recovered, either in place on the control surfaces, or separated, but in nearby areas.

The right-hand aileron was recovered in two pieces separated by a fracture through WS 495 at the leading edge and WS 505 at the trailing edge. The upper surface of the fracture was irregular, with jagged ends turned upward, but the lower surface had a relatively smooth tension-type failure. The upper surface of the aileron exhibited faint shear wrinkles which progressed outboard and aft.

The WS 448 hinge fitting was torn free and recovered on the hinge support bracket, which had separated from the wing rear beam. This bracket was bent inboard. The hinge support bracket at WS 380 failed approximately 11 inches forward of the hinge pin. The aileron hinges at WS 380, 448, and 585 showed evidence of aileron upward overtravel, with crushing of the sheet metal around the upper clearance cutouts.

The right-hand aileron push-pull tube was recovered in one long section and several small sections. The long section remained in place on the main wing section and extended inboard to WS 185. The bellcrank support bracket near WS 380 was failed.

The left-hand aileron was found in two large pieces and one small piece. These pieces were all separated from attached structure. The upper and lower surfaces exhibited slight compression buckles in the area of WS 516, but were relatively undamaged elsewhere except at the forward end of the inboard section, which was buckled and wrinkled. This aileron also exhibited evidence of upward overtravel.

Both inboard jackscrews and one outboard jackscrew, right-hand side, were recovered along with the wing flaps. Both inboard jackscrews were recovered in a condition corresponding to fully retracted landing flaps. The right-hand outboard jackscrew was in a condition corresponding to a flap extension of 17° to 18".

The right-hand elevator was recovered in four major pieces, with chordwise fractures near the hinge points at HSS 80, 147, and 200. The inboard and outboard sections remained attached to parts of the horizontal stabilizer and the others separated from all structure. Almost the entire length of the leading edge was crushed aft and, over the hinges, upward, in a manner which indicated the elevator had overtraveled upward. No fire damage was observed on these pieces and the sooting was irregular, varying from heavy on the lower surface of the outboard piece to none on the upper surface of the adjacent piece. The lower surface generally exhibited more sooting than the upper surfaces.

The left-hand elevator was intact and in place on the stabilizer and exhibited no sooting or heat damage. The entire upper surface exhibited random buckling and the lower surface was deeply dented near HSS 230. The outboard 40 Inches of the trailing edge was bent upward 1-1/2 to 2 inches and the upper leading edge was deformed downward in this same area.

The rudder was in place on the vertical stabilizer, intact, and relatively undamaged except for damage on the leading edge and right-hand side. This damage extended from VSS 44 to 60, and 24 inches aft from the leading edge, through the front beam. The damage continued aft in the form of a split in the skin and a chordwise buckle in the trailing edge at VSS 48. There was light, unsymmetrical buckling over the entire surface and somewhat less severe buckles on the left side. The trailing edge was crushed slightly forward in short lengths extending over much of the rudder span.

The fuselage structure was demolished by the impact and sections identified consisted of flattened pieces of skin and stringers with the floor beams separated or broken. Damage was more extensive in the forward areas and on the right side. Fewer pieces of the right side were identified and those which were identified were generally smaller than those from the left side. Little evidence of fire was observed on the structure ahead of the wing. The pieces aft of the wing displayed evidence of sporadic fire exposure which was most pronounced in the area between FS 678 and 920. No evidence that an explosion had occurred was noted on any of the fuselage pieces examined.

All of the main passenger doors and most of the fuselage service doors separated from their attached structure, and were found in the main impact area.

All three landing gear uplocks were found, separated from all structure, in the unlocked position. The nose landing gear uplock could be moved by hand; however, both main landing gear uplocks were jammed.

The right main landing gear actuating cylinder was attached to the aircraft structure but the gear structure, to which it attached, was burned away. The piston was in the fully compressed position -- its position when the gear is extended. The left main landing gear actuating cylinder was separated from the gear and was attached to a 12-inch square piece of rear beam which had separated from the aircraft. The cylinder was fully extended, which is the gear-up position. The piston was extended 22 inches and the attach lug was failed in tension. The nose landing gear actuating cylinder was found free of all structure with the piston failed. A 12-1/2-inch piece of the piston remained attached to the gear structure. The landing gear selector valve was' recovered with the plunger fully inserted which corresponds to a gear-up selection.

All the landing gear doors, except the left-hand nose landing gear door, were found in the final impact area or in the vicinity of the main section of the right-hand wing. Most of the left-hand nose gear door was found in three pieces in outlying areas. The forward piece, which had a maximum length of 33 inches, terminated at a propeller cut. This cut began at the end of a 9-inch black scuff mark, with a serrated edge which progressed diagonally aft 15 inches from the scuff.

The Nos. 1 and 2 engines and propellers were separated from the wing and each other. The No. 3 engine power section, torque meter, and rear gearbox case and mounted accessories remained attached to the right wing section which had separated from the aircraft. The No. 3 propeller attached to the reduction gear assembly was separated from the engine power section. All four blades were either attached or lying directly adjacent to the hub. The No. 4 engine and propeller assembly remained attached to the right wing section.

There was no evidence that the crew had intentionally shut down any engine and this was confirmed by the CVR recording.

The propellers were disassembled and examined and it was determined that they were all operating at time of impact. There was no evidence that any of the blades had separated from the hubs before the accident occurred. There was no necking down or physical damage incurred by the blades to indicate that one or more of them had been subjected to an in-flight overspeed. Furthermore, no evidence of a propeller overspeed was found on the CVR record.

The propellers were examined for evidence of a recent lightning strike but none was found.

Four separate and independent procedures were used in an effort to determine the propeller blade angles that existed at the time of the accident. The most reliable method was found to be the installation of the master gear on a slave hub assembly and measuring actual blade angle travel from the "as received" position to the mechanical low pitch stop. The average blade angles obtained were as follows:

No. 1. ∠ 52°	No. 2. ∠ 48°
No. 3. ∠ 18°	No. 4. ∠ 49"

Since the No. 3 propeller blade angle was not in agreement with the other three propellers, a further examination was made of this component. It was calculated that an 18° pitch angle at 200 knots would have caused a propeller overspeed which would have been so extreme as to elongate the blade shank or caused blade separation due to extreme tensile overloads. No elongation, stretch, or other evidence of tensile overload was found during detailed measurements of the blade shank outside diameters and shank wall thicknesses. Finally, three bevel gear teeth were found sheared from the master gear assembly. The direction of the shear forces was such that they would have moved the master gear toward the low pitch setting when such shear forces were applied.

The autopilot components were so badly damaged as to preclude any determination of their use at the time of the accident. The hydraulic control boost packages were examined by the manufacturer, and all of the packages responded in a normal manner when tested under conditions similar to those of aircraft control surface operations. During this testing, the hydraulic fluid samples taken from the packages were found to be contaminated with water, and the surfaces of the internal parts and the valve bodies were corroded and pitted. Except for the contamination and corrosion, the units were normal in all other respects.

Cockpit components were found in various places in the primary impact area. The captain's instrument panel was recovered with all of the instruments missing. The various instruments were severely crushed and indented. One gyrosyn compass repeater provided an indication of 320". Readings of 29.78 were found on the barometric pressure settings of two altimeters. An electric turn-and-bank indicator was found indicating a full right turn and displaying a "power off" flag.

No attitude information was available from the two gyro horizon indicators. Most of the other recovered instruments did not show any useful information.

All instruments were later examined for evidence of arcing within the bearing assemblies. No arcing was found.

The airborne weather radar control panel was recovered crushed to about one-third of its normal width and its parts torn free within its enclosure. With the assistance of the manufacturer, electric measurements were taken from the resolver within the panel. It was ascertained that the radar scanner position was 8-1/2° up-tilt. The resolver was trapped in such a position as to prevent movement of its rotor. The resolver rotor and body were in the same position when tested as they were when recovered after the accident.

1.13 Fire

Witnesses reported the aircraft was burning when it fell to the ground. There was a ground fire in the primary impact area and in the area where the main portion of the right wing came to rest on the ground. There was no indication of an in-flight fire prior to the initial failure of the right wing.

1.14 Survival Aspect

This was a nonsurvivable accident.

1.15 'Pests and Research

Because there was a possibility that stress corrosion and/or prior damage might have contributed to the failure of the right wing, special studies of metallurgical samples were made by the National Transportation Safety Board, the National Bureau of Standards, the Naval Research Laboratory, and the manufacturer.

Samples for these studies were taken from the following portions of the right wing:

Upper surface access door WSS 119

Upper surface plank No. 3 filler well WS 90

Upper surface trailing edge plank No. 8, WS 130

Upper surface WS 65 to 155 through fracture area

Lower surface through fracture area WS 65 - 155	Lower surface plank No. 2 WS 417
Lower surface plank No. 1 WS 417	Fracture area outboard of No. 4 nacelle
Horizontal stabilizer R. H.	Vertical stabilizer
Rudder post	Wing tanks 3 and 4
Lower surface Plank No. 1 right wing WS 221-311	Aileron push-pull tube
Rudder post	Left nose landing gear door
Lower surface plank No. 1 right wing WS 101	Upper surface right wing adjacent to access door between WS 101 - 137
Upper surface plank No. 2 WS 482	Lower surface right wing plank No. 1 between WS 257 and 275
Rudder post flange	3 pieces No. 3 engine gearbox

Unused sample of upper surface wing plank material of the type used adjacent to the access door between WS 101-137

These samples were submitted to various types of testing and examination by the various laboratories, including visual examination, hardness tests, high magnification optical examinations, examination by electron microscopes, tensile tests, detailed measurements, laboratory test fractures produced by mechanical overload, and induced stress corrosion cracking in the sample wing plank material.

The testing performed by the manufacturer led them to conclude that there was no evidence of material deficiencies, fatigue damage, or stress corrosion; nor was there any indication of electrical or lightning discharge damage. The National Bureau of Standards and the Naval Research Laboratory investigated samples from the fracture area in the upper surface of the right wing adjacent to the access door between WS 101-137.

The National Bureau of Standards concluded that dimpled rupture (evidence of ductility) was found at the fillet edge of all fractures examined by them, except one. This latter fracture had evidence of severe corrosion at the fillet edge of the fracture. They reported that there was a possibility that a stress corrosion crack, approximately 1.5 mm. deep and of unknown length, might have existed in this section prior to a final overload failure. They also stated that the occurrence of surface corrosion and/or mud cracks does not constitute positive identification of stress corrosion cracking in a fracture surface of 7178-T6 aluminum alloy extrusion. They noted that the corrosion might have occurred on the fracture surface after failure as evidenced by examination of two additional fractured samples of wing plank.

The Naval Research Laboratory reported that, on the basis of their investigation, no definitive answer could be given as to whether the failures they examined were due to stress corrosion or simple overload fracture.

The Board's examination, visual and metallographic, did not reveal any evidence of stress corrosion cracking in the samples from the fracture in the top surface of the right wing adjacent to the forward edge of the access door between WS 101 and 137. All the fractures in the two pieces examined from the No. 2 plank, upper surface, right wing were typical of gross overload breaks in the wing plank material. The sample from the spanwise break in the bottom surface of the right wing adjacent to the front beam cap between WS 221 and 311 showed characteristics typical of overload tensile shear fracture. The fractures in three pieces of the No. 3 engine gearbox were typical overload breaks, and showed no evidence of prior damage such as fatigue cracking.

At the request of the Board, the manufacturer conducted an Investigation to establish the various conditions which could produce wing bending moments sufficient to fail the wing. Symmetrical pullouts, gust conditions, and unsymmetrical accelerated roll conditions were investigated as a function of load factor at two speeds, The selected speeds were 250 and 350 knots equivalent airspeed (KEAS).

The investigation considered the aircraft with a takeoff weight of 96,300 pounds, 18,000 pounds of fuel and a c.g. of 30.5 percent MAC. The weight at the time of the accident was considered to be 94,000 pounds with 15,700 pounds of fuel in the wings and a 30.2 percent MAC c.g. An altitude of 7,000 feet was used in all cases.

Representative wing stations near the apparent points of failure, WS 101 for the inner wing and WS 380 ⁄ for the outer wing, were selected for the wing load calculations. The calculated loads for these stations included shear, bending moment, and torsion about the wing elastic axis.

The load factor attainable at various equivalent airspeeds and the load factor at which stall buffet initiated were determined. The data was based on structural demonstrations of the Lockheed Model P3V Orion which has a wing aerodynamically similar to the L-188. Incremental gust load factor variation was also calculated at nominal gust intensity at 250, 300, and 350 KEAS.

The wing bending moments for the inner wing were determined at 250 and 350 KEAS. Extensive analysis of wing gust loads on the L-188 has shown that, at the wing root, dynamic gust conditions derived from the static gust loads are more severe than the static gust loads, *so* the bending moments included both static and dynamic gust loads. Similar calculations of wing bending moments at WS 380 ⁄ were made for 250 and 350 KEAS. In this case however, static gusts are expected to be more critical than dynamic gust loads in this region of the wing. The bending moments calculated for 250 KEAS are also applicable at a speed of 275 KEAS.

These data were plotted, and the intersection of these curves with the calculated bending moment strength line established the load factor at which the wing could fail at each station under the various loading conditions. It was noted that the actual strength might vary a few tenths of a "g" from the indicated values due to tolerances in manufacturing, material properties, gages, and other considerations.

Where buffet was a factor, the load factor for start of buffet and the dynamic maximum load factor were considered. Buffet increments of bending moment were added to the calculated values above the load factor corresponding to the onset of buffet. Increments of 18 percent at WS 101 and 25 percent at WS 380 were used. These increments were based on stall buffet flight tests conducted on the YP-3A and P-3A aircraft. While there was considerable scatter in the test data, the values used were considered representative of the average experience. These "failure" load factors were summarized, and interpolated values for 300 KEAS were calculated. A review of this data indicates that the most likely speed for failure was approximately 275 KEAS and was equally likely to result from either maneuver or gust loads. The failure could occur at either the wing root or outboard of the outboard nacelle at a load factor of 4.2 to 4.5. An abrupt roll at 250 KEAS could cause a failure at WS 380 at a load factor of 3.7 but, for all other conditions at 250 KEAS, the aircraft would stall before failure.

A second study was made which correlated the FDR data, the trajectory study, the NASA attempts to re-create the terminal flight maneuvers, NACA data regarding the distribution and frequency of unsymmetrical spanwise gusts, and an FAA report of continuous turbulence gust analysis of the L-188. The symmetrical gust loads previously used were also re-evaluated.

The previously reported study had indicated that the aircraft probably broke up at an airspeed of about 275 knots while undergoing a load factor of between 4.2 and 4.5. The review of the NASA study and the FDR record indicated that the aircraft probably broke up in the speed range of 300 to 330 knots indicated airspeed (KIAS). The previously calculated wingloads showed that the load factor to cause failure at WS 101 in the speed range of 300 to 350 KIAS was 4.7 to 5.4. In view of this difference and the calculated load factor at failure of 4.3, additional studies were made to determine whether some other condition could produce failure loads at 4.3 "g".

The additional studies indicated that one such condition was an unsymmetrical gust. The NACA study indicates a high frequency of occurrence of unsymmetrical spanwise gust distributions. Loads were calculated for a gust which peaked at WS 380 on the right wing, reduced to zero at the left wingtip, and reduced to half peak value at the right wingtip. At WS 101, the bending moment per "g" was 25 percent greater than the value of a symmetrical gust.

The study also indicated that a more realistic relation between c.g. acceleration and wingloads was available from the continuous turbulence gust analysis of the L-188 as reported by the FAA. That report indicated that the c.g. acceleration occurring with the same probability as a load sufficient to break the wing was 4.77 "g". The actual c.g. load factor that might occur in association with wingloads equal to wing strength could differ from this value by at least several tenths of a "g".

Two reasons were given for this possible difference.

One was that the turbulence input and therefore the airplane response were defined only statistically. Depending upon the actual time history of gust velocity during the few seconds before the wing reached ultimate strength, the relative contributions of elastic mode response and "static" response might vary considerably. The ratio of maximum c.g. acceleration to maximum wingload would vary accordingly.

A second reason was that the 4.77 "g" value was obtained considering *only* symmetrical gusts. Inasmuch as turbulence tends to be isotropic, lateral and rolling gusts generally will also be present. Both of these would increase the wing bending moment somewhat without affecting the c.g. acceleration. The lateral gust would introduce bending moment through elastic mode excitation and the rolling gusts would introduce bending moment both statically and through elastic mode excitation. The 25 percent increase in bending moment per "g" previously mentioned for an unsymmetrical gust reflected only the static effect of a rolling gust.

The FAA report also indicated that positive wing torsions tend to be higher than the values calculated by discrete gust methods. Since bending strength was affected by torsion, new loads were calculated for a speed of 342 KEAS and plotted on a bending-torsion strength envelope. Lines were shown for a pure maneuver, a gust from 1 "g", and a gust from a 2.5 "g" maneuver. Load factor scales were shown along each load. line. For gust conditions, two scales were shown, one representing a symmetrical gust and one representing an unsymmetrical gust. From this information, the wing strength was calculated under any combination of maneuver and gust. Gust intensity was denoted both as derived gust velocity and true gust velocity. For unsymmetrical gusts, the gust velocity scales represented an average gust velocity.

A review of these data shows that the wing strength at WS 101 could be reached at 4.3 "g" at 324 KEAS under a combination of maneuver and unsymmetrical gust loading. Note that the aircraft response to transient gust and abrupt maneuvers might be different from those used in these load calculations so that c.g. accelerations corresponding to wing strength could be reached at a 4.3 "g" load factor. The report stated that since turbulence tends to be isotropic, it is reasonable to consider an angled gust with a component acting forward with respect to the aircraft. This gust component would be too transient to affect the aircraft's speed with respect to the ground, but the flow over the wing could be momentarily slowed to a speed where buffet would occur at 4.3 "g".

The sequence of failure was investigated and a study made to establish the flight conditions which would be necessary to cause failure of the horizontal tail or vertical tail. These studies were made considering an undamaged aircraft because, if the wing failed first, the loading conditions on the empennage would be entirely different and the pitch and yaw motions could easily produce loads to cause failure of the empennage. Balanced maneuvers, vertical gusts, and abrupt checked maneuver pullup loads were considered. Buffet increments taken during stall penetration flight tests of the P-3A were also considered. Only the abrupt checked maneuver pullup produced a loading condition which could cause a failure of the horizontal tail in upbending in the considered configuration.

Investigation of the sideslip angle necessary to fail the vertical tail included the maximum attainable dynamic overswing yaw angle due to rudder kick, and the yaw angle attained from a turbine failure of an outboard engine with a simultaneous failure of the Negative Torque System and decoupler safety devices. This investigation indicated that neither rudder kicks nor engine failure could cause failure of the vertical tail. Investigation of the lateral gust required to fail the tail at 250 and 300 knots indicated the nominal derived gust velocity would have to be approximately 128 feet per second (f.p.s.) or 108 f.p.s. respectively.

Because the right wing was broken at two spanwise locations, near the root and outboard of the outboard nacelle, an effort was made to explain either break as the second failure. If the first break occurred in the outer panel, no way to fail the wing at the root was found. The only likely way the outer panel could fail, after failure at the root, appeared to be dependent on damage having been incurred during the initial failure at the root.

Another project performed by the manufacturer at the Board's request was a trajectory study to attempt to determine the point in space where the initial breakup occurred.

The investigation was based on conventional calculation techniques including the solution of equations of motion with input parameters of weather, flight conditions existing immediately prior to the accident, and the drag determination of the parts studied.

Because of the thunderstorm activity in the local area, precise weather information was not available. Consequently, weather information provided by local witnesses was used. Although the effect of the wind associated with the thunderstorm complicated the trajectory analysis, it provided a means of verifying the estimated drag of various components and in establishing the aircraft heading at the time of the initial failure.

The headings studied ranged from 180° to 225°, the altitudes from 6,000 to 10,000 feet, the airspeeds from 220 to 350 knots, and initial descent rates from 0 to 750 feet per second. Various combinations of these conditions were studied.

These studies indicate that the aircraft most probably was descending at a rate of 480 feet per second, at an indicated airspeed of 330 knots, on a heading of 200° true, at an indicated altitude of 6,750 feet when the initial breakup of the aircraft occurred. The average wind velocity was calculated as 33 knots from 342° true. This indicates that the aircraft's initial breakup point was 2,700 feet north and 800 feet east of the final impact point. These data compare favorably with the flight recorder data at time "37 minutes 14 seconds."

This study indicated that most probably the right wing and empennage separation occurred almost simultaneously and that the No. 1 and 2 powerplants, left flaps, left aileron, and left wing leading edges separated from the left wing a few seconds later. The study noted that severe and unusual weather conditions existed at the time of the accident, and these may have influenced the accuracy of the study.

Another task performed by the manufacturer at the request of the Board was to ascertain the physical capability of a complete, undamaged L-188 to accomplish the heading, altitude, and speed changes shown on the flight data recorder trace for the last 30 seconds of flight.

They concluded that, in several major areas, the flight data recorder information was consistent with the estimated aerodynamics and physics of the situation. They stated there was reasonable correlation between the calculated angles of bank, indicated turn headings, and increasing load factors, as well as between longitudinal acceleration and flightpath gradient in the early and intermediate portions of the final time period shown on the flight recorder.

They believed it probable that the aircraft suffered an upset which resulted in a rapid speed buildup prior to the initial structural failure. They also concluded that a complete aircraft was capable of developing the longitudinal accelerations, altitude changes, and load factors shown on the flight data recorder, prior to the time of the suspected initial structural failure. The recorded parameters on the flight data recorder, subsequent to the suspected breakup point, can be correlated to calculated aerodynamic data to a fair degree. Finally, they believe that there was a strong possibility that the recorded heading might have been in error for at least a portion of the maneuver.

As a part of the investigation of this accident, the Board requested NASA to perform tests and demonstrations with an aircraft simulator. The primary objective of this work was to determine whether an undamaged aircraft could be maneuvered in a manner to produce the variations of the flight parameters exhibited on certain portions of the flight data recorder tape. The results of these tests indicated that a rational re-creation of the terminal flight recorder indications of altitude, airspeed, and total heading change could be produced by maneuvering the simulated airplane to maintain an approximation of the normal acceleration values recorded in the accident aircraft, and by rolling, at a moderate rate, from a moderately banked, right climbing turn to a right-bank angle of approximately 105°.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

It was obvious, quite early in the investigation, that loads in excess of the airframe strength had been imposed on the structure, but the nature and origin of these loads were not immediately apparent. As a result of this, the remainder of the investigation was organized about two premises -- that the in-flight structural failures were a result of either an overload condition or of inadequate aircraft strength. Possible causes of an overload condition which were considered included an encounter with some extreme weather condition, a combination of forces or accelerations produced by weather and pilot response, or by some pilot-induced maneuver. Areas which could have rendered the aircraft understrength included fatigue or other prior damage, defective material used in construction, or deficiencies in design structural strength.

The long history of the L-188, coupled with the results of our investigation, indicates that the design structural strength was not the cause of this accident. Thereafter, the Board's investigation was aimed at attempting to learn whether the accident was caused by an overload or had resulted from the effects of prior damage.

Our investigation of the possibility of prior damage to the aircraft developed the fact that the aircraft had been exposed to two incidents of turbulence, requiring a turbulence inspection, as well as high in-flight and landing loads during a series of flights terminating in a left main landing gear-up accident. Following each of these occurrences, the records indicate that the aircraft was inspected, and following the landing accident repaired, in accordance with the existing requirements. After the second turbulence incident in December 1966, the aircraft was returned to service and operated until May 3, 1968, without any reported exposure to turbulence or other form of overload or damage.

Our investigation has revealed no indication that any prior damage existed in the primary structure of the aircraft as a result of these exposures to in-flight and landing overloads.

Another possible source of prior damage to the aircraft was cracking of the wing material due to stress corrosion or other causes. A review of the FAA's records pertaining to all U.S.-registered L-188's showed a total of 545 reports of wing cracking or corrosion and included reports of 748 separate cracks. Approximately 89 percent of the reported cracks and/or corrosion were reported to have been in the wing area between the fuselage and the No. 2 or 3 engine nacelles. Approximately 54 percent of the reports pertained to the right wing and 51.5 percent of the reports pertained to the upper surface of the wing assemblies. The accident aircraft had only four reports of cracking or corrosion of wing planks prior to this accident. These consisted of one report in each of the years 1964, 1965, 1966, and 1967. The first three reports listed a total of 14 cracks, 13 of which were found in the left wing. One crack of 39.5 inches was found in the right wing No. 4 upper plank, between WS 110.5 and WS 150. This area is just outboard of the area where the right wing initial failure occurred in this accident.

The possibility that prior damage caused the wing to fail at less than its ultimate design load will probably never be completely discounted. No evidence of such a failure was observed and we believe that this mode of failure is unlikely.

If stress corrosion did in fact exist, the prior damage probably consisted of a small spanwise crack. The manufacturer's stress reports show that the structure in this area has considerable tolerance for spanwise cracks before the margin of safety is reduced appreciably. Therefore, the effect of the small stress corrosion crack postulated by one of the metallurgical laboratories would be negligible. The possibility that a large crack was not observed, possibly because it was located in the missing portions of planks 1 and 2, is considered unlikely. Had the failure been precipitated by a crack, the nature of the failure would most likely have indicated the failure source. The chordwise wing loading was fairly consistent, judging from the uniformly small size of the pieces of plank and the straightness of the compression buckle along WS 101. Had the failure originated at a crack, it would likely have been progressive in nature. The pieces would then have been larger since less total energy would have been required to fail the wing, and the fracture propagation would have occurred as a 45" tear across the primary tension field in the plank surface, or roughly at a 45" angle across the wing planks.

Among the types of overloads considered by the Board in the investigation of this accident were those caused by: lightning-induced explosion, weather phenomena including gusts and turbulence loads, pilot-induced maneuver loads, and a combination of weather- and pilot-induced loads.

Witnesses reported that a flash of lightning was observed near the aircraft. This lightning stroke was followed by a flash of fire or explosion, and the aircraft fell to the ground, enveloped in flames.

The Board has considered the possibility that this lightning stroke might have triggered an explosion in a fuel tank or ignited fuel fumes, and that the overpressure weakened the structure to the point of failure. With the exception of the evidence of overpressurization in the outboard end of the No. 4 fuel tank, there was no evidence which could support this theory. Had an explosion occurred near the right wingtip, it was unlikely that the remainder of the wing could have failed as it did, and we are left with no explanation of the aileron overtravel which occurred to the right aileron. The possibility that a lightning strike might have ignited fuel or vapors without the occurrence of a catastrophic explosion was also explored. In this case the failure of the wing might have resulted from heat damage to the structure. This theory was rejected because it was not consistent with the available evidence which indicates that no fire occurred before the wing broke up.

A third possible effect of lightning was also considered. This was the possibility that a lightning strike, or nearby flash of lightning, caused the pilot to lose control of the aircraft either by temporarily blinding him or by affecting his basic attitude instruments. According to the statements of the witnesses who reported lightning, the flash occurred almost simultaneously with the appearance of the fire. Our analysis of the flight recorder readout indicates that the upset was initiated about 20 seconds before the failure of the wing, at which time the fire first appeared. Therefore, we conclude that the flash of lightning, which was observed at about the time and place of the appearance of the fire in the sky, cannot be considered in causal relationship to this accident.

The Board believes that, as the aircraft approached the storm system which lay across its intended path of flight, it began to encounter moderate or slightly more than moderate turbulence. The pilot commenced a gentle bank to the right approximately one-half minute before the in-flight failure occurred. Within the period from 10 to 15 seconds after the initiation of this turn, the captain indicated a desire to make a 180° turn, a total excursion of 2.7 "g" occurred, and the bank angle increased to a calculated average value of 66°. In the next 10 seconds, the calculated average bank angle exceeded 110° and the aircraft attained a descent angle of nearly 40°. We believe that the aircraft was first upset laterally, possibly by a gust encounter, just as the pilot attempted to increase his right bank, and the lateral upset progressed into a lateral-longitudinal upset or a spiral maneuver.

During the attempted recovery from this spiral, the inboard section of the right wing was subjected to positive bending and torsional moments in excess of its ultimate strength. Because of the effect of the rolling moment created by the attempt to level the wings, the left wing was not subjected to loads as high as those imposed on the right wing.

The initial failure of the structure was a chordwise compression failure of the right wing upper planking at WS 101. This failure was a result of overstress of the material and, if any prior damage did exist, it did not contribute significantly to the failure. The lightning stroke occurred at approximately the same time that the high maneuvering recovery loads were reaching the ultimate strength of the wing. The ball of fire occurred after the integrity of the integral wing fuel tanks was disrupted by the failure of the wing structure.

The remaining structural failures sustained by the aircraft were either a direct consequence of the right wing failure at WS 101 or of the descending maneuvers of the fuselage-left wing combination.

The exact path of the initial fracture as it progressed through the wing box section components is not certain because much of the material from this area was not identified. However, enough was identified to ascertain that this section of the wing was subjected to positive spanwise bending overloads with some leading edge up torsion at the time it failed. The failure probably originated as a chordwise compression buckle of the upper surface at WS 101. The lower surface fractures disclosed the existence of torsional loads on the wing. The failure was primarily tensile in nature in the forward wing planks, but the longitudinal splitting and twisting evident in the diagonal fractures in the aft planks was indicative of torsional-shear loading.

The rear beam failure probably originated at WS 141. The section of beam between WS 101 and 141 was bent aft on both inboard and outboard ends. These aft bends were caused by aft bending moment acting on the beam after the continuity of the forward part of the box beam section was interrupted.

This evidence indicates the wing failed, with the wingtip and wing leading edge moving up relative to their normal position, and with the wingtip moving aft. The initial failure occurred in the section of the wing, which is usually critical for compressive stress in the positive high angle of attack loading condition. Such a loading condition normally occurs in a pullout from a dive.

The torsional nature of the outboard wing front beam and lower surface failures is not consistent with the mode of failure which would be expected if the wing box section was intact at the time these parts failed. Although the diagonal rupture which existed in the lower surface was not apparent in the upper surface, the extensive longitudinal fracturing of the upper surface between WS 397 and 516 is indicative of torsional loading at failure.

Because of this extensive torsional deformation, we believe that the primary failure of this section of wing occurred in the rear beam which appears to have been pulled away from the box section. The fracture of the rear bean at WS 397 is consistent with that type of fracture which would be caused by aileron loads. Excessive hinge moments applied to the WS 380 rib could cause failure of first the rib and then the rear bean itself. The first failure in this area was probably the separation of the upper chord from the top plank. However, this same loading does not appear to have been responsible for the outboard fracture where the rear beam failed primarily in tension at WS 516. The fracture between the chord and the upper planks progressed inboard from WS 515 to 448. The nature of this failure and its location seem more suggestive of an overpressure, probably caused by fuel hydraulicking, than of aileron overloading. This belief is further supported by the oily soot or dirt streaks left on the right aileron by fuel flowing over its surface. These streaks were roughly chordwise and were more pronounced on the inboard end and the upper surface of the aileron.

The right horizontal stabilizer failed in positive bending -- a direction opposite to that in which it is usually loaded, particularly in a positive high angle of attack condition. The sooting seen on the exterior and interior surfaces and on the fracture surfaces of the outer part of the stabilizer indicates clearly that this was a secondary failure. The stabilizer was also washed by unburned fuel. This must have occurred when the stabilizer was intact, since the flow was aligned with the normal airflow over the surface. It is evident that the stabilizer was engulfed in burning fuel which was ignited sometime after the wing fuel tanks ruptured. The amount of soot inside the outer section leads us to conclude that raw fuel was ingested by the fractured end of the stabilizer and this fuel burned as the part fell. The source of the loading which failed this surface was probably inertial forces generated by the rapid roll of the aircraft immediately following wing separation. Another source of loading which may have contributed to the failure was an up airload caused by the loss of downwash, normally generated by the wing, after the wing had separated.

The left stabilizer did not fail but separated intact, taking its fuselage attach structure with it. The source of loading in this case was probably the asymmetric tail load on the fuselage which resulted after the separation of the right stabilizer.

The vertical stabilizer, which separated to the left, also appears to have failed as a result of inertial loads. This stabilizer was struck by the leading edge of the right horizontal stabilizer, leaving red paint marks on the leading edge of the horizontal stabilizer from the lettering on the vertical stabilizer. Although the damage caused by this strike was extensive, it did not cause the failure of the vertical stabilizer. The right-hand attach stringer at FS 1185, which was broken by the horizontal stabilizer, also fractured below that point in the plane of the vertical stabilizer failure. This lower fracture was tensile failure at a point where the cross-sectional area of the stringer was approximately 1 square inch. For 7175 aluminum in this state, a force of 80 to 100 kips would have been required to cause the tensile failure. If the stringer had been broken above this point, sufficient load to cause the lower failure could not have been transmitted into the angle by the surrounding structure.

Both ailerons overtraveled upward. The left aileron overtravel is believed to have occurred during the gyrations which resulted after the right wing separated, since the outboard hinges were driven so far into the wing trailing edge. The right aileron overtravel was fairly uniform and not nearly as extensive as that of the left. This overtravel appears to be consistent with that which the aileron push-pull rod might be able to cause if the rod were loaded to its structural limit in tension. We believe the rod was loaded to its structural limit in tension after the initial wing failure at WS 101.

No evidence was found to indicate that any in-flight fire existed before the wing failed. Except for the empennage area, the smaller pieces of structure which separated in flight were generally unburned and unsooted. The only indications of in-flight fire were the soot patterns on the right horizontal stabilizer and the heat damage on the trailing edge and flap sections of the main piece of the right wing.

The fact that the initial failure occurred in the right wing is clearly established by the soot and fuel wash patterns on the horizontal stabilizer. The stabilizer had to be in place after the integrity of the fuel tanks was disrupted. However, a review of the wreckage scatter pattern indicates that both the right wing failures and the empennage failures occurred very close together in time, since parts from both areas were found together along the eastern edge of the scatter pattern.

While it was established that the initial failure occurred in the right wing, it was not as clear whether the failure began inboard or outboard of the engines. The nature of the rear beam damage at the outboard fracture indicates that both an upward aileron deflection and the previously mentioned hydraulicking of the fuel in the No. 4 tank were present at the time of the breakup. Both of these conditions can be explained if the inboard failure occurred first. The pull on the aileron push-pull rod as the wing separated would result in an upward overtravel of the right aileron. Furthermore, a relatively high internal pressure would have been produced at the outboard end of the No. 4 fuel tank by the inertial loads forcing fuel outboard during a rolling pullout and by the rapid rotation of the wing during the breakup. Conversely, if the initial failure was outboard of the engines, then there is no rational explanation for the manner of failure in that area, and it is unlikely that the remainder of the wing could have failed as it did.

The crew of the accident aircraft had flown from Dallas to Houston several hours prior to their departure from Houston returning to Dallas. At that time, there was no thunderstorm activity in the area which would have affected their return trip, and this observation may have influenced their interpretation of the weather warnings and SIGMET's provided to them on their departure from Houston. The company and Weather Bureau data available to the crew contained adequate information regarding the condition and extent of the severe weather, with minor inaccuracies as to location and time. Regardless of the accuracy of the weather forecasts, the crew observed the storm from a point at least 60 miles away, from an altitude of 20,000 feet. They were also advised, after requesting a deviation to the west, that other aircraft, including company traffic, were deviating to the east. The airborne weather radar on board the aircraft should have delineated the eastern edge of the storm area as well as any low spots between cell tops. The evidence indicates that while the storm system was extensive to the west, there would be low spots between the tops of the cells. These low spots could have been misinterpreted by the crew as a "light area" or separation between cells, particularly if the radar antenna was tilted up 8°, as the recovered radar antenna cockpit control found in the wreckage indicates. If this condition existed, the presentation on the aircraft radarscope would continue to be misleading as the aircraft approached the storm. In this connection, we note that at 1646:09, in response to an inquiry from the controller, the crew of Flight 352 indicated that the area they were flying toward was not clear but they thought they saw an opening through it. This comment was followed by a request for any reports of hail in the area.

Hail, having generally a lesser reflectivity to radar than other forms of moisture, coupled with misleading information presented by a higher than normal antenna up-tilt, could have induced the crew to continue to press for a deviation to the west. We do believe, however, that the fact that the crew knew that another Braniff flight, coming from the west, was deviating to the east parallel to the storm front, taken in conjunction with the repeated comments from the controller regarding deviations to the east, should have been sufficient reason for the captain of Flight 352 to reconsider his decision to penetrate the weather area.

After the penetration of the storm had been initiated, the decision to reverse course was not in keeping with recommended company procedures for operation in areas of turbulence. Normally, once in an area of turbulence, the crew is expected to maintain the attitude of the aircraft as nearly straight and level as possible and maneuvering is to be kept to a minimum until the turbulent area is cleared. The possibility of gusts being added to control inputs, and resulting in an upset, is a consideration that must be assumed by the pilot.

Because of certain apparent anomalies in the flight data recorder readout, the Board analyzed the recorder readout in an attempt to clarify the recorded data. These anomalies were apparent time reversals in the indicated heading and airspeed traces near the end of the recording. They occurred during the short period of time following the apparent upset and attempted recovery. During this period, the aircraft was being subjected to violent and rapidly fluctuating accelerations. In addition, the heading and airspeed were changing very rapidly due to aircraft maneuvering, and the heading trace was also being affected by gimbal errors. Under these conditions, the advance rate of the record medium can be very erratic and can even reverse in direction momentarily. In addition, extremely rapid movement of the styli can cause slight wrinkling of the aluminum foil. The aberrations, in our opinion, invalidate the indicated advance or reversal of time for this very brief period and also serve to confirm that the aircraft was being subjected to extremely violent and rapidly fluctuating accelerations. There is nothing in this situation, however, to cause us to doubt the validity of the magnitude of the recorded data points.

The Board then analyzed the readout in an attempt to define the terminal maneuvers of the accident aircraft. This analysis indicated that the aircraft commenced a 24° bank at 1647:10 and maintained this bank for 10 seconds. During this 10-second period, a load factor of 1.1 "g" would have been required to maintained the 24° bank angle in level flight. The centroid of the "g" trace peaks on the readout were considered to be the average acceleration for the time period under consideration and were determined to be 1.3 for the first 5 seconds and 1.1 for the second 5 seconds. The heading and acceleration traces were therefore consistent for that time period.

From 1647:20 to 1647:25, the aircraft attained an average minimum bank angle of 66°. The average "g" for this period period was 1.0, while the theoretical value required to maintain level flight with 66° bank is 2.5 "g". No reason for this discrepancy can be found. This period may well mark the beginning of a lateral upset. This period began with a statement by the captain "Let's make a 180°," and in the 3 seconds following that statement, the "g" trace progressed from 0.1 to 2.8 "g". Assuming that the captain began his 180° turn at the time of his statement, a gust or gusts could account for increase in "g" reflected during that time period, and this may have caused the captain to exceed his desired angle of bank, which we would normally expect to be about 30°.

During the next 5-second period, the minimum bank angle required to produce the observed heading change in a coordinated turn was 72° and the theoretical normal acceleration to maintain altitude at that angle of bank was 3.1 "g". The recorded acceleration was an average of 1.5 "g". The value of 3.1 was calculated for level flight, and the altitude trace shows the initiation of a descent (or a downward acceleration) during this time period. This downward acceleration is 14.4 feet per second squared (f/s^2). Calculations of the lift-weight vectors for a level 72° turn and those for a descending turn, in which the rate of turn is the same as the level turn but the vertical component of the lift vector reflects the 14.4 f/s^2 downward acceleration, were prepared. These calculations resulted in a new angle of bank of 80". The vertical acceleration during this period resolves into a 1.5 "g" acceleration normal to the longitudinal axis of the aircraft. Adding this to the 1.5 "g" recorded by the flight recorder results in a total 3.0 "g", which compares favorably with the 3.1 "g" required to produce the recorded heading change with a coordinated 72° bank.

Five-second time intervals were chosen for these calculations to give an average view of the critical parameters over a relatively long period of time. In an attempt to determine the maximum bank angle attained, a shorter time interval was necessary to obtain a maximum figure instead of an average. This procedure also tended to reduce the effects of gyro-gimbal error. During this time period, a maximum bank angle of 115° was required to accomplish the heading and altitude trace changes derived from the flight recorder readout.

During the time period from 1647:30 to 1647:35, the altitude trace shows the initiation of a steep descent, with a maximum rate of 16,200 feet per minute at the end of the period. At an average airspeed of 210 knots indicated airspeed, this represents a descent angle of over 37°. During this time span, the aircraft was entering into a longitudinal upset or a steep spiral. This longitudinal upset might have been induced partially by a gust which caused the roll increase and partially by the loss of vertical lift caused by the steep angle of bank. If a gust were involved, it would have to have been an upward gust. With the aircraft in a right bank, a vertical gust would have had a right side-slip component as well as a pitch component. The directional stability of the aircraft would then have caused it to nose downward. However, the loss of vertical lift or the negative lift component resulting from the steep angle of bank would have been adequate to cause the descent by itself. During this time period, the heading trace indicated a decreasing rate of change and the average bank angle reduced to 52°.

During the time period 1647:35 to 1647:42, the traces generally appear to be aberrant and no attempt was made to determine the precise aircraft maneuvers from these data. However, the rapid increase in airspeed ceased and the acceleration increased correspondingly, rising to 4.3 "g" which occurred at 1647:42. Correlation of the heading, airspeed, and acceleration traces for this period leads the Board to conclude that the terminal maneuver was an attempt to recover from a spiral descent and, during this attempt, loads in excess of the structure's ultimate capability were developed on the right wing.

An overload failure of the wing could also have been produced by a gust encounter. In this case, this possibility was ruled out Largely by the flight recorder readout. No acceleration trace excursions, resembling those caused by gusts, approached the ultimate strength of the structure. The only load factor representations on the flight data recorder trace that approached the ultimate limit of the structure are those which are more typical of maneuvering loads. By the time this load was applied, the aircraft had already experienced a sudden descent and there were other indications that the aircraft was not in normal flight. Even though the aircraft was in a meteorological environment where intense vertical and lateral gusts were likely, the flight recorder readout shows no large vertical accelerations prior to the loss of control. Since the flight recorder does not record lateral gusts as accelerations, it cannot be ascertained whether intense lateral gusts actually existed. The vertical accelerations shown on the recorder readout related only to light-to-moderate turbulence.

The Board believes that this accident occurred due to a combination of circumstances, any one of which, in isolation, would not have caused the accident. The crew's attempt to penetrate the weather area astride their route to Dallas was an unsound decision. Their real difficulties began when they changed their minds and attempted to turn out of the area. The turbulence encountered up to that time was not severe enough to damage the aircraft; however, it probably played a part in upsetting the aircraft after the pilot began his 180° turn. This lateral upset then progressed to a longitudinal upset because of the loss of vertical lift caused by the steep bank. Upon detecting this problem, the pilot then attempted a rolling pullout by rolling the aircraft back to the left and applying back pressure on the controls. During this maneuver, the loads applied to the aircraft were in excess of the ultimate strength of the aircraft and the right wing failed at about WS 101. All the subsequent structural failures were secondary to this initial failure.

2.2 Conclusions

(a) Findings

1. N9707C was certificated and maintained in an airworthy condition as prescribed by FAA regulations.

2. N9707C had been involved in a previous accident.

3. N9707C was repaired and inspected in accordance with FAA regulations for a "hard landing."

4. N9707C was not checked for alignment after being subjected to excessive in-flight loads while attempting to get a main landing gear down, nor was such a check required.

5. It has been calculated that the L-188 wing could fail at 275 KEAS at a load factor of between 4.2 and 4.5 "g" and at the same approximate load factor in a speed range of 300 to 350 KIAS in unsymmetrical gusts. A failure at 275 KEAS, at a load factor between 4.2 and 4.5 "g", could result from either maneuver or gust-induced loads. It is also possible to fail the wing in the 300 to 350 KIAS speed range under a combination of maneuver and unsymmetrical gust loading.

6. The flight recorder of N9707C recorded a 4.35 "g" maximum load at failure.

7. There was no overspeed of any of the propellers.

8. All aircraft systems were capable of normal operation, and there was no evidence of a malfunction of any of the systems prior to breakup.

9. There was no evidence of a lightning strike on N9707C.

10. The crew was certificated and qualified in the type aircraft they were operating.

11. The crew had personally observed the weather during its formative stage while on a flight from Dallas to Houston.

12. The flight was being operated at Flight Level 200.

13. The crew observed the storm system 60 miles ahead of them, requested deviation to the west, and to descend to 15,000 feet.

14. Fort Worth Center controller answered the request for deviation to the west with a suggestion that deviation to the east would be better, and added the information that all other flights were deviating to the east. The controllers restated that all other flights were diverting to the east in two succeeding transmissions while the flight was progressing toward the storm front.

15. Braniff 352's crew insisted on deviation to the west.

16. A westerly deviation and penetration would have been a shorter route and would have taken less time.

17. Braniff 352's crew should have been aware of the direction of movement of the storm system to the southeast from weather information available at Houston and their earlier observations.

18. The crew's personal observation of the atmospheric conditions on their earlier flight would tend to offset the warnings contained in the forecast weather warning and SIGMET.

19. The weather conditions were forecast by the U. S. Weather Bureau and Braniff Airlines with only slight errors in time and location.

20. Braniff 352 was held at altitude (14,000) to allow company traffic to pass underneath.

21. The traffic delaying Braniff 352's descent was coming from farther west and was paralleling the storm system in order to clear it to the east.

22. Just prior to Braniff 352's entering the storm cell, the air traffic controller asked if the area they were penetrating was clear.

23. The crew of Braniff 352 responded in the negative but stated they "thought" they saw a hole through the storm.

24. Braniff 352's crew asked if there were any reports of hail in the area.

25. The storm cell precipitation echo blocked out all other targets on the air traffic controller's scope in the area of the storm even though circular polarization was in use.

26. The controller did not inform Braniff 352 that radar contact was lost.

27. The captain of Braniff 352 told the copilot not to talk to the air traffic controller too much because they were "trying" to get the crew to admit they had made a big mistake by going through the storm system.

28. The captain of Braniff 352 ordered a reversal of course.

29. The flight was immediately cleared by the controller to make the course reversal turn in any direction.

30. The flight recorder traces were studied by three separate groups.

31. The consensus of the groups was that the aircraft was upset subsequent to the initiation of a right turn to reverse course.

32. During the upset, N9707C rolled to the right to a bank angle in excess of 90°.

33. N9707C pitched nose down to approximately 40°.

34. The heading information being fed to the flight recorder would be erroneous in steep bank angles due to "gimbal errors."

35. The NASA studies indicate the maneuver which preceded failure of the wing of N9707C was well within the control and performance capabilities of the Electra aircraft.

36. A rapid rate of descent is correlated with the observed erroneous heading rates of change on the flight recorder record from N9707C.

37. A rapid increase in airspeed is correlated with the high rate of descent and erroneous heading rates of change.

38. As the rapid increase in airspeed ceases, an acceleration force increase begins and "peaks" out at 4.35 "g".

39. The slope of the heading trace starts to flatten out at 1647:26, indicating that a roll recovery maneuver had been initiated.

40. Immediately following the initiation of the right turn for course reversal, "g" forces fluctuating between ≁ 0.2 and ≁ 1.6 indicated the aircraft was encountering vertical gusts.

41. The initial structural failure was the compression failure of the right wing upper planking at WS 101.

42. This failure was the result of positive bending and leading edge up torsional moments in excess of those for which the aircraft was designed.

43. No evidence of any significant pre-existing structural damage was observed in the wreckage, and the nature of the primary failure is not that which would be expected if a crack had precipitated the failure.

44. No in-flight fire existed before the integrity of the wing fuel tanks was disrupted by the breakup. The fuel so released was ignited by some means, creating the ball of fire observed by ground witnesses.

45. The lightning, which occurred at about the same time the ball of fire was observed according to ground witnesses,' was not a factor in this accident.

46. A study of the flight recorder readout indicates that the aircraft entered into first a lateral and then a longitudinal upset approximately 20 seconds before a 4.35 "g" peak was reached on the acceleration trace. At the time of this high maneuvering load factor, the aircraft was in the process of recovering from the spiral upset.

47. The recovery maneuver involved a left rolling pullout from a dive.

48. The failures of the outer right wing and empennage were initiated by forces, accelerations or control movements generated by the inboard wing failure. The left wing parts which separated came off during the descending gyrations of the fuselage-left wing combination.

49. At the time of breakup, the flaps were retracted and, during the breakup, the landing gear extended. The right aileron was forced into the full-up position when the aileron push-pull rod was pulled as the wing separated.

50. The breakup of N9707C occurred at an altitude of about 6,750 feet, 2,700 feet north and 800 feet east of the initial impact point.

51. Eyewitnesses did not observe the initiation or the turn for the reversal of course of N9707C.

52. None of the eyewitnesses observed N9707C for the last 30 seconds prior to breakup.

53. Eyewitnesses in the best position to have observed N9707C reported seeing it between clouds and then disappearing into the storm.

54. These eyewitnesses support the air traffic controller and Weather Bureau witnesses's testimony that N9707C entered the leading edge of the storm.

55. Visual perception of the pilot might have been reduced by a near lightning stroke.

56. The reduction of visual perception or the startling effect of a near lightning stroke should not have been sufficient to cause over-control of the magnitude to cause an upset by an experienced airline pilot.

(b) Probable Cause

The Board determines that the probable cause of this accident was the stressing of the aircraft structure beyond its ultimate strength during an attempted recovery from an unusual attitude induced by turbulence associated with a thunderstorm. The operation in the turbulence resulted from a decision to penetrate an area of known severe weather.

3. RECOMMENDATIONS

Based on the Board's findings of contaminated hydraulic fluid and corrosion of some of the hydraulic components of the aircraft, the Board recommended to the Federal Aviation Administration that their Air Carrier and General Aviation Inspectors be alerted to the necessity of constant vigilance with respect to all operators' procedures and practices in all aspects of fluid handling. The Administrator concurred with this recommendation and advised the Board that "our position is re-emphasized in the text of a maintenance bulletin being processed for early issue to Flight Standards field offices." This bulletin was published August 30, 1968.

In a separate action, the Administrator issued an Airworthiness Directive, effective November 6, 1968, requiring all known U. S. operators of Lockheed Model 188A and 188C airplanes to inspect the No. 1 wing plank at engine nacelles 2 and 3 for cracks, and to repair those cracks found as necessary.

Because of its concern with accidents which have occurred during periods of severe weather, the Board conducted a survey of representative air carriers to examine their policies and procedures for operation during such conditions. The survey indicated that, in general, the carriers do have appropriate policies and procedures for operations during periods of severe weather, including the requirement for airborne weather radar to be used primarily as a thunderstorm avoidance tool rather than a penetration aid. Nevertheless, despite the policies, procedures, and special training and informational programs, accidents involving severe weather have occurred.

Accordingly, the Board took the following actions: A letter was transmitted to the Administrator of the FAA recommending that Parts 121 and 135 of the Federal Aviation Regulations be amended to prohibit penetration of thunderstorm activity occurring in an area for which tornadoes and/or severe thunderstorms have been forecast. It was also recommended that as an interim measure until standards could be developed, a requirement be made that these storms be avoided by at least 20 nautical miles. A letter was transmitted to all air carriers stressing the need for all personnel to adhere to published' policies and procedures, with emphasis placed on the use of airborne weather radar for storm avoidance purposes. This letter also invited the reader's attention to the FAA's Advisory Circular 00-24, "Thunderstorms," and advocated that it be required reading for everyone in the aviation business who is called upon to deal with severe weather conditions, whether he be on the ground or in the cockpit; and a letter was forwarded to the Administrator of the Environmental Science Services Administration (ESSA), the parent organization of the Weather Bureau, recommending changes in procedures to provide for the inclusion, in SIGMET messages, of the associated details of thunderstorms such as hail size, turbulence intensity, etc., whether or not the thunderstorms are of the severe category.

In its reply to the Board, the FAA indicated, in part, concurrence with the intent of the recommendations to amend the Federal Aviation Regulations but considered that, at that time, the answer rested in the education and training of pilots and dispatchers.

The ESSA reply stated that they would conduct a thorough review of the procedures for the issuance of SIGMET's, in coordination with other Government agencies, including the Safety Board, and with industry groups.

ESSA subsequently sponsored a Government-industry meeting to review the procedures regarding the issuance and wording of SIGMET's; representatives from the air carriers, general aviation, and military aviation were present. The majority decision of this group was that the present procedures were working well, and that the primary limiting factor preventing additional data in SIGMET's was a lack of available teletype circuit time. They also agreed that if additional circuit time became available, they would like to receive additional specific information in the SIGMET's. ESSA stated that when sufficient circuit time becomes available, the Board's recommendation will be reviewed again.

Although the Board's letter to the air carriers did not require a response, many of the carriers did respond and it is evident to the Board that, as a result of its letter, large segments of the aviation industry were reviewing, amending, and updating safety and training programs and operational procedures.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

Crew Information

Captain John R. Phillips, aged 46, was originally employed by Braniff January 3, 1946, as an apprentice stock clerk. He joined the flight department on October 1, 1951. He completed his initial qualification as captain in the Convair 340, February 7, 1966, after previously being qualified as a first officer ,of L-188 aircraft in July 1964. He completed his initial line check as a captain in the L-188 February 15, 1967, and then qualified as a captain in the B-727 but flew the B-727 exclusively from the beginning of February through May 2, 1968. On May 2, 1968, he passed a recurrency check in the L-188 which consisted of three full-stop landings. The captain who gave this check described the landings as "beautiful" and stated that Captain Phillips knew the aircraft very well.

Captain Phillips was observed on check rides five times by the FAA when he was a first officer and four times as a captain in the B-727 with no adverse comments regarding his flying record.

Captain Phillips possessed ATR No. 491749, dated 12/14/65, with ratings for aircraft multiengine and single-engine land, flight instructor, CV-340/440, L-188, and B-727. He passed a first-class physical examination January 11, 1968.

The captain had a total pilot time of 10,890 hours including 1,380 hours in the L-188. He had flown 149 hours in the last 90 days and 42 hours in the preceding 30 days. He had logged 511 hours total instrument time with none recorded in the preceding 90 days.

During the 24 hours prior to the accident, he had 16:50 hours available for rest and had been on duty 7:10 hours including 2:41 hours of flying time. The last flight lasted approximately 48 minutes. His proficiency and line checks were current.

First Officer John F. Foster, aged 32, was employed by Braniff June 1, 1966, as a second officer (flight engineer) but was initially trained as a first officer on Convair aircraft. He was then upgraded to first officer on the L-188. Mr Foster held a commerical pilot certificate No. 1516437 with ratings for aircraft multiengine and single-engine land, rotorcraft, and instrument. He passed his last first-class physical examination April 9, 1968.

His total pilot time was 2,568 hours with 1,820 hours in the L-188. He had flown 143 hours in the preceding 90 days and 70 hours in the preceding 30 days. He had logged a total of 305 hours instrument time but had flown none in the preceding 90 days.

During the 24 hours prior to the accident, he had 18:49 hours available for rest and had been on duty 5:11 hours. He had flown 2:11 hours during this period of duty. Mr Foster's proficiency and line checks were current.

Second Officer (flight engineer) Donald W. Crossland, aged 28, was hired by Braniff March 6, 1967. He possessed commercial pilot certificate No. 1698427 and flight engineer certificate No. 1760997. He held airplane multiengine and single-engine land and instrument ratings on his commercial certificate. He passed his last first-class physical October 16, 1967.

Mr Crossland had a total of 1,000 hours pilot time and 754 hours of flight engineer time, all of the latter being in the L-188. He had flown 181 hours in the last 90 days and 67 hours in the last 30 days. During the 24 hours preceding the accident, he had 18:49 hours available for rest and had been on duty 5:11 hours. He had flown 2:11 hours during this time. His proficiency and line checks were current.

The two assigned hostesses were regularly employed and had completed their initial training in 1967.

Captain Phillips completed L-188 training with average to above average grades. His instructor stated that he was a bit rough on the controls initially, which he considered normal for a Convair pilot transitioning to the L-188, but smoothed out after a period or two of instruction and performed quite satisfactorily. His ground school record indicates he received instruction in meteorology including information on thunderstorms and their avoidance March 8, 1965, and August 7, 1966. He also received at least six lessons between 1964 and 1967 on the use of the airborne radar.

Braniff instructions to their aircrews do not include instructions on how or where to penetrate thunderstorms, and their manuals indicate that thunderstorms are not to be penetrated. Each aircraft does, however, have procedures for turbulence penetration. The Braniff L-188 Operations Manual, dated March 19, 1964, stated as follows: "Turbulence - the rough airspeeds are from 170 to 190 knots, the higher airspeeds being applicable to Plights at or near maximum gross weights. . . . When flying in moderate turbulence, airspeeds up to 250 knots can be safely used since this figure provides a safety factor in the event a strong gust is encountered." (phis same page stated that "Flight through known severe turbulence should be avoided if possible." If severe turbulence is encountered, the manual stresses attitude flying while operating in that environment.

The Eraniff Flight Manual also provided information to aircrews regarding thunderstoms and other potentially hazardous weather conditions. That manual read in part: "Severe thunderstorms may produce or be accompanied by hail and/or tornadoes. Since hail may fall suddenly from the overhanging cloud canopies of cumulonimbus clouds, they should be detoured by at least 2-3 miles to avoid possible hail strikes." However, a thunderstorm avoidance pamphlet issued by the Eraniff Technical Training Department indicated that, when operating below the freezing level, the clouds of a thunderstorm should be circumnavigated by a minimum of 5 miles.

Aircraft Information

N9707C was a Lockheed Electra L-188, owned and operated by Braniff International. The aircraft records indicate that it was manufactured on October 17, 1959, and was purchased by Braniff on that date.

The aircraft had a total time of 20,958 1/ hours prior to the departure from Houston to Dallas, May 3, 1968. It had flown 10 hours since the last Terminal Check which was performed on April 29, 1968; 21 hours since the last Intermediate Check, April 28, 1968; and 618 hours since the last Periodic Check, January 20, 1968.

The aircraft was equipped with four Allison General Motors Model No. 501-D13A engines and Allison Model No. A6441FN-606 propellers. All these components were operating within their respective overhaul times.

The aircraft Maintenance Log Forms from January 1965 to February 1968, and the Aircraft Maintenance Log from April 1, 1968, through May 3, 1968, were reviewed. There were no reported hard landings in these records. A review of the FAA's Daily Mechanical Reports, Braniff records, and Civil Aeronautics Board records revealed that on two occasions pilots had reported that the aircraft had been subjected to in-flight turbulence which warranted an inspection and additionally, the aircraft had been involved in a landing accident when the left main landing gear would not extend.

On June 13, 1961, the pilot reported that he had encountered in-flight turbulence of approximately 1.5 positive and 1.0 negative "g". A review of the flight data recorder tape by Braniff indicated that the aircraft had recorded 4.3 positive and 0.5 negative "g" during the flight. A turbulence inspection was performed and no damage was found. The aircraft had approximately 3,362 hours flying time recorded at that time.

Another pilot report of turbulence was made December 7, 1966, with a request for a turbulence inspection. The records indicated that a turbulence inspection was performed December 8, 1966, per the Lockheed Aircraft Repair Manual. No discrepancies were noted during this inspection and no repairs were performed on the aircraft.

This type of inspection is essentially a visual inspection and there is no requirement for an alignment or symmetry check of the aircraft. The aircraft operated from December 1966 until the accident

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1/ All flying times are reported to the nearest whole hour.

without any other reported exposure to excessive in-flight loads. During the record period examined, from April 1, 1968, through May 3, 1968, there was a total of 97 flights wherein no discrepancies were noted, and none of the noted discrepancies on other flights relate to the aircraft structure.

On July 20, 1966, N9707C landed at Kansas City, Missouri, and because of a subsequent landing accident the next morning, the flight data recorder tape was examined. The readout of the tape shows a "g" spike of approximately 3.25 at about the time of touchdown at Kansas City. A review of the aircraft records shows that no hard landing was reported by the flightcrew. On a later leg of the flight, the crew was unable to extend the left main landing gear and they attempted, by various flight maneuvers, to extend the stuck gear. During these maneuvers the flight recorder indicates three "g" spikes: One of approximately 3.5 "g", another approximately 3.3 "g", and a third of approximately 2.8 "g". During the ensuing landing, with the left main landing gear retracted, the readout reflects several spikes of approximately 2 "g". Following this accident the aircraft was inspected and repaired. The inspection, which included a hard landing inspection, revealed no damage to the aircraft other than that attributed to the landing accident. No symmetry or alignment checks were performed on the aircraft.

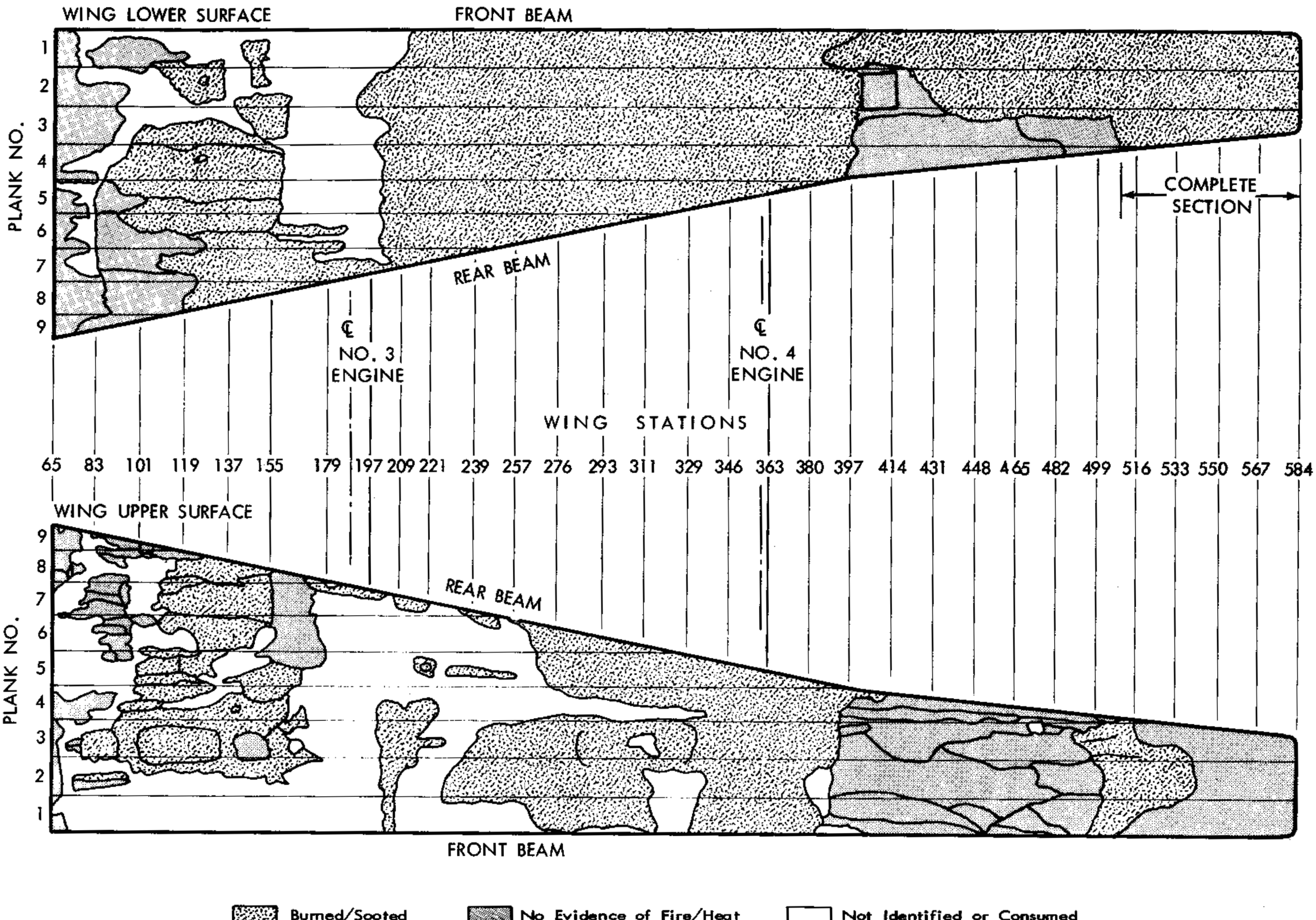
The Electra wing is composed of three major components, the center section which extends from Butt Line (BL) 65 through the fuselage to BL 65 R; the outer wing which extends from BL 65 to Wing Station (WS) 584 on each wing; and the wingtips. Both the wing center section and outer wing box beam have upper planks made of 7178-T6 material and the lower planks are made of 7075-T6 material. wing plank splice inspections cover three basic categories: surface corrosion, stress corrosion cracks, and fatigue cracks. The inspections consist of both visual inspections and nondestructive inspections using ultrasonic, eddy current, dye penetrant, and X-ray inspection equipment. X-ray inspections of the wing sections between engine nacelles is performed every 3,000 hours. The last nondestructive inspection recorded was performed on this aircraft January 20, 1968. No cracks were found.

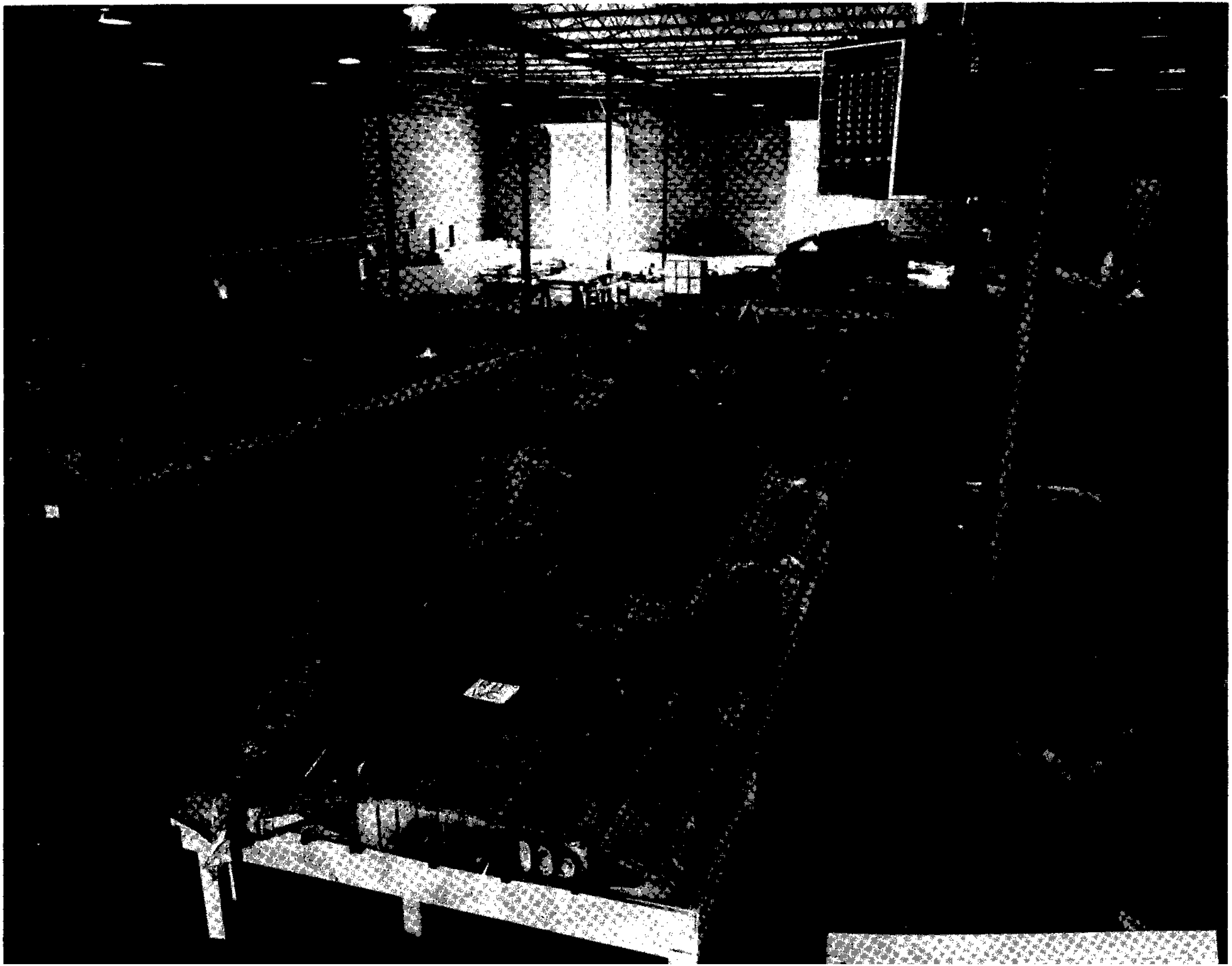
All pertinent Airworthiness Directives relating to the L-188 had been complied with on N9707C, according to the records.

The aircraft was properly certificated and airworthy at the time of its departure from Houston, according to the records. The records also indicate that the aircraft was being maintained in accordance with existing FAA and company requirements. The weight and balance were current and within limits at takeoff from Houston and at the time of the accident.

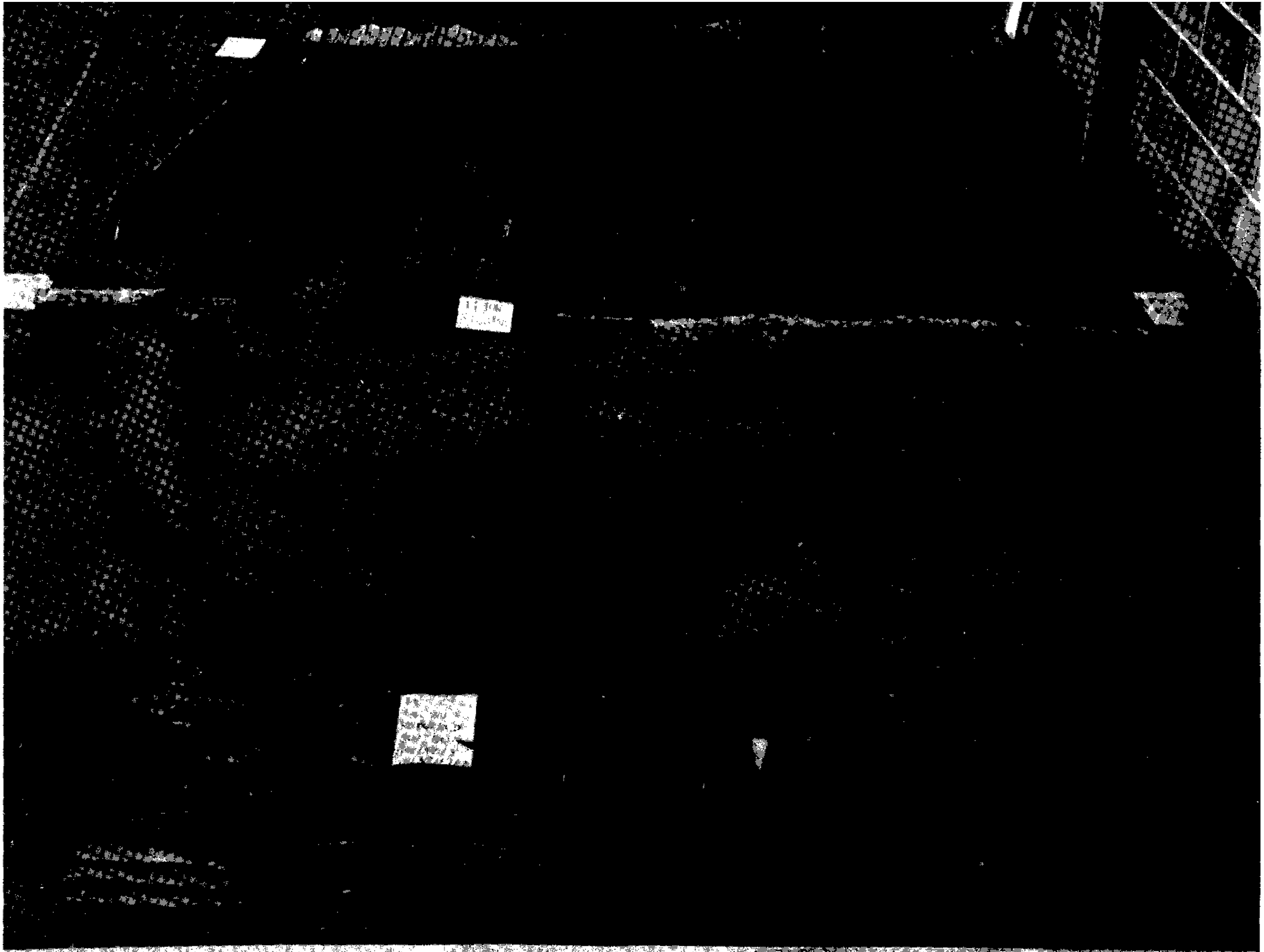
Not to scale

RIGHT WING PLANK LAYOUT

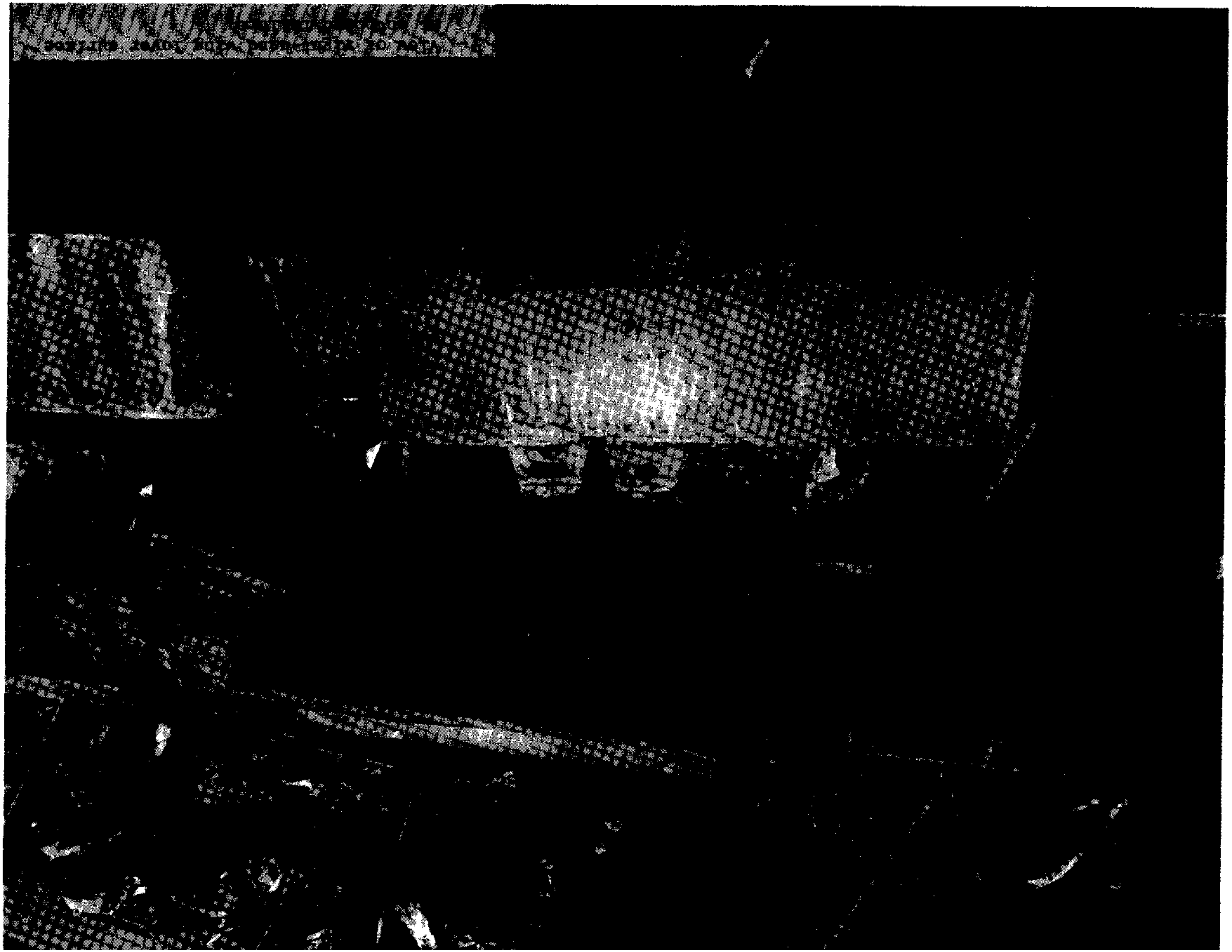


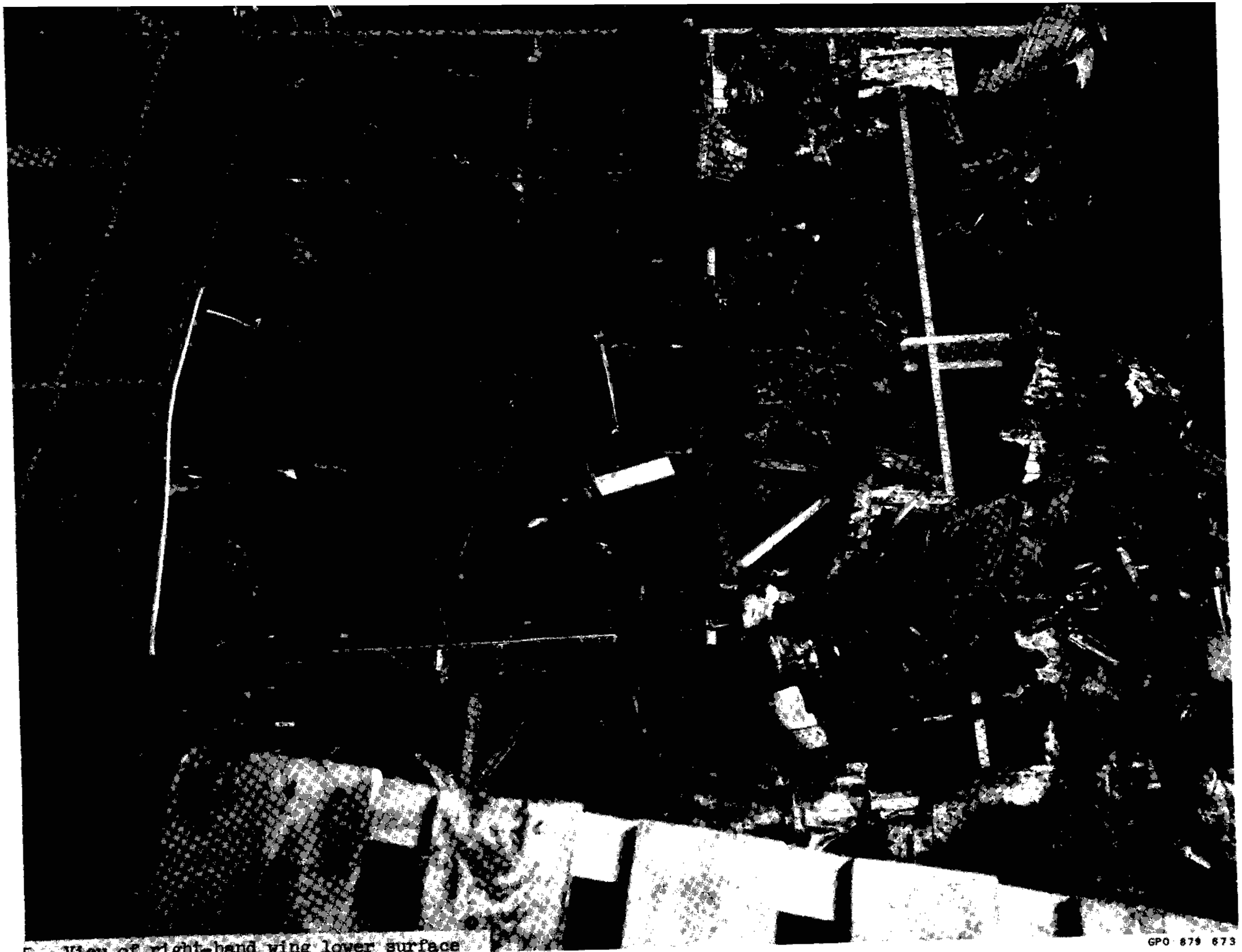


View of right-hand wing upper surface



3. View of right-hand wing upper surface at inboard failure.





5. View of right-hand wing lower surface at inboard failure.

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