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Aircraft Accident Report

NASA 712, Convair 990, N712NA
March Air Force Base, California
July 17, 1985

Facts and Analysis

NASA Aircraft Accident Investigation Board
National Aeronautics and Space Administration
Washington, D.C. 20546

July 1986

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AIRCRAFT ACCIDENT REPORT

NASA 712, CONVAIR 990, N712NA
MARCH AIR FORCE BASE, CALIFORNIA
JULY 17, 1985

SYNOPSIS

On July 17, 1985, at 1810 P.d.t., NASA 712, a Convair 990 aircraft, was destroyed by fire at March Air Force Base, California. The fire started during the rollout after the pilot rejected the takeoff on runway 32. The rejected takeoff was initiated during the takeoff roll because of blown tires on the right main landing gear. During the rollout, fragments of either the blown tires or the wheel/brake assemblies penetrated a right-wing fuel tank forward of the right main landing gear. Leaking fuel ignited while the aircraft was rolling, and fire engulfed the right wing and fuselage after the aircraft was stopped on the runway. The 4-man flightcrew and the 15 scientists and technicians seated in the cabin evacuated the aircraft without serious injury. The fire was not extinguished by crash/fire/rescue efforts and the aircraft was destroyed.

The NASA Aircraft Accident Investigation Board determined that the probable cause of the accident was the nearly simultaneous failure of the two front tires on the right main landing gear at a critical time during the takeoff roll. These failures resulted in the pilot's decision to reject the takeoff. Contributing to the severity of the accident was an intense fire fed by leakage from the puncture of a right-wing fuel tank forward of the right main gear; the puncture occurred during the intentional extended rollout of the aircraft.

1.0 FACTUAL INFORMATION

1.1 History of the Flight

On July 17, 1985, at 1000 P.d.t.[1], NASA 712, a Convair 990 (CV-990) turbojet aircraft operated by the NASA Ames Research Center (ARC), Moffett Field, Mountain View, California, departed its home base for March Air Force Base (AFB), Riverside, California, to support a scientific flight later in the day. The aircraft landed at 1100; no significant discrepancies were noted during the flight. The flight positioned the aircraft closer to the intended mission area, 18° north latitude. The aircraft was scheduled to take off at 1800 for a 6-hour flight under instrument flight rules (IFR) to observe a man-made barium comet trail. The aircraft flightcrew consisted of two pilots, a flight engineer, and a navigator. Fifteen scientists and technicians were onboard to operate the experimental equipment.

While the flightcrew, the scientists, and the technicians rested at a local motel, a maintenance throughflight check was completed on the aircraft by Northrop Services contractor personnel. The only discrepancy noted was a minor cut on the tread of tire 7 (fig. 1). The cut was circled with yellow

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[1]All times are Pacific daylight saving time based on the 24-hour clock.

chalk and determined to be within normal operating tolerances. This same circled cut was later found on a piece of tire carcass during the runway examination. The cut was still within acceptable limits. The main gear tire pressures were checked in accordance with standard ARC practice and reported to be within the normal range, 165 to 170 psi. The tire pressures were not recorded on the aircraft's maintenance forms since there was no requirement to do so.

ARC policy limited the maximum ramp weight of the aircraft to 240,000 pounds. Northrop maintenance personnel stated that the aircraft had 89,700 pounds of fuel onboard before engine start as indicated on the aircraft fuel gauges. This established an aircraft ramp weight of 232,500 pounds. In post-accident interviews the crew stated that they had calculated a decision speed V_1 of 151 knots, a rotation speed V_R of 154 knots, and an initial climb speed V_2 of 167 knots. March AFB runway 32 is 13,300 feet long, and the balanced-field length was calculated to be 10,500 feet. The takeoff engine pressure ratio (EPR) power setting was 1.87. The aircraft takeoff center of gravity was 23.4 percent of mean aerodynamic chord (MAC), which was within limits. The investigation team confirmed these figures as correct for the meteorological conditions at the time of the accident.

The aircraft commander occupied the right seat. The pilot occupied the left seat and was operating the controls. The engine start was normal. Taxi was without incident until a "thump" was heard/felt in the cabin by those familiar with the aircraft. Subsequent discussion attributed the "thump" to the air-conditioning system. The cockpit crew stated that they had also noted the "thump" but had not discussed it.

The aircraft was cleared onto runway 32 by March AFB tower to hold in takeoff position. At 1806, NASA 712 was cleared for takeoff by the tower controller with the final instruction "change to departure, cleared for takeoff." The crew set the radios to the departure frequency, and the pilot advanced the throttles and checked the engines at an intermediate power setting. After the engine checks he released the brakes and advanced the throttles to the 1.87 EPR setting.

The flightcrew stated that everything was normal in the cockpit during the first part of the takeoff roll. However, the occupants of the cabin and several witnesses outside the aircraft noted abnormalities. A technician, watching a television monitor linked to a camera focused on tire 3, noticed deformation of the tire. Another technician occupying a right-side cabin seat aft of the wing had a fleeting perception of a "black object flying over the wing." An outside witness made a similar comment. Other witnesses, who were positioned about 2 miles from the aircraft, noticed white smoke coming from the aircraft underside early in the takeoff roll. There was no indication of these abnormalities in the cockpit, nor did the cabin occupants relay their observations to the flightcrew.

As the aircraft accelerated, the pilot heard two rapid explosive bangs and immediately felt a "kind of quivering of the aircraft." The cockpit voice recorder (CVR) recorded two almost simultaneous explosive sounds. The flightcrew recognized the sound as a blown tire. The aircraft commander, who was responsible for calling the speeds to the pilot, recalled seeing the airspeed indicator pass 140 knots. The flight engineer recalled "seeing a speed of 135 to 140 knots." Several technicians in the cabin were in the habit of monitoring and cross-checking inertial ground speed readouts, and they recalled a reading of 144 knots at the time of the explosions. The flight data recorder (FDR) indicated that 143 knots was the maximum speed attained, a velocity of about 242 feet per second. The CVR indicated that the aircraft commander called out "abort," almost simultaneously with the flight engineer's call of "blown tire." A rejected takeoff (RTO) was begun. The pilot closed the power levers, deployed the spoilers, and selected reverse thrust on all four engines. Being aware that the runway at March AFB was 13,300 feet long (2,800 feet longer than the calculated balanced-field length), the pilot informed the crew that he was going to "stay off the brakes." In later interviews the pilot stated that he used light braking during the rollout. During the first phase of the RTO the aircraft swerved slightly to the right, and the pilot acted to bring the aircraft back toward the runway centerline. He further stated that during the rollout he had difficulty steering with the nose wheel and recalled thinking that the nose wheel tires may have blown out. The remainder of the cockpit crew and one technician seated forward in the cabin stated that the pilot appeared to have difficulty with directional control using the nose wheel steering. In addition, the aircraft commander stated that he was not holding the control yoke forward during the rollout.

Nine seconds after the first explosions, another bang was heard by the flightcrew and recorded on the CVR. The flight engineer stated "blew another one." Five seconds later the CVR recorded the application of reverse thrust. As reverse thrust was being applied, another bang was recorded on the CVR but was not noticed by the flightcrew. During the rollout the pilot stated he was not sure on which side the tires had blown but, based on the sound, thought that they were on the left side.

The tower controller perceived the aircraft to be in distress and in the process of aborting after about 6,000 feet of takeoff roll. The controller tried to contact NASA 712 on tower frequency. The flightcrew did not receive the transmission since they had changed to Ontario departure control frequency before beginning the takeoff roll and were not monitoring tower frequency on any of the three radios. The tower controller later noted flames on the aircraft and immediately activated the primary crash network.

The pilot reduced reverse thrust on all engines after the flight engineer called "3,000," as recorded on the CVR. Approaching the end of the runway and without knowledge of a fire, the pilot started a right turn toward the last taxiway in an attempt to clear the runway. After hearing a call of "fire on the right side" from the technicians in the cabin area, the pilot immediately brought the aircraft to a stop at about 12,700 feet. The engines were shut down by using the emergency shutdown handles. The aircraft commander released his seatbelt and shoulder harness and opened the right cockpit window to assess the situation. He noted fire near the right landing gear and raw fuel pouring out of the wing in front of the right landing gear and immediately ordered the flightcrew to evacuate the aircraft.

The 15 cabin occupants, being aware of the fire before the flightcrew, had started preparing for evacuation before the aircraft came to a stop. Since the fire was on the right side, the left-side emergency evacuation slides were deployed - one at the front exit and one at the rear exit. Although there were minor problems with the deployment and operation of the slides, the entire crew exited safely.

After the evacuation, all crewmembers and occupants assembled at a safe distance from the aircraft and awaited the arrival of the crash/fire/rescue (CFR) equipment. They noted that the fire was fed by a large column of ignited fuel pouring from a right-wing tank in front of the right main landing gear. The crewmembers and other witnesses described it as a "column of fire." The right wing and the fuselage were completely destroyed by the fire.

The accident occurred during daylight hours, about 1810 at 33° 52.8' north latitude and 117° 15.5' west longitude. The elevation of the accident site was 1,537 feet mean sea level (m.s.l.)

1.2 Injuries to Persons

None of the four crewmembers nor the 15 scientists and technicians on board were injured. Two firefighters were slightly injured while attempting to extinguish the fire.

1.3 Damage to Aircraft

The aircraft fuselage and right wing were consumed by the fire. The aircraft was destroyed.

1.4 Other Damage

To meet research mission requirements, the NASA CV-990 aircraft cabin was extensively equipped with electronic equipment used in a variety of scientific flight research programs. All of this equipment was destroyed. The portland cement concrete (PCC) surface on the departure end of runway 32 at the aircraft stop point was significantly damaged.

1.5 Personnel Information

The flightcrew were all properly certified and trained for the flight (appendix A). The 15 scientists and technicians onboard had all been briefed on safety and evacuation procedures.

1.6 Aircraft Information

The aircraft was operated and maintained as a public aircraft in accordance with Ames Research Center guidelines and procedures. The maintenance was performed by Northrop Services under contract to ARC (appendix B).

1.6.1 Tire service history. - The wheel, brake, and tire positions on the CV-990 main landing gear were designated by number, left to right, beginning with the forward tires (fig. 1). Nos. 1 and 2 were the forward positions of the left main gear; nos. 3 and 4 were the forward positions of the right main gear; nos. 5 and 6 were the rear or aft positions of the left main gear; and nos. 7 and 8 were the aft positions of the right main gear. The nose tires, wheels, and brakes were identified as left and right.

The tire (24 ply) in the no. 3 position was 12 years old and on its sixth retread cycle; the tire (22 ply) in the no. 4 position was missing a digit from its serial number, making the year of manufacture (1973 or 1983) indeterminate. However, since this tire was on its fourth retread in 1984, it was most likely manufactured in 1973. The tire (24 ply) in the no. 7 position was 12 years old and on its fourth retread; and the tire (22 ply) in the no. 8

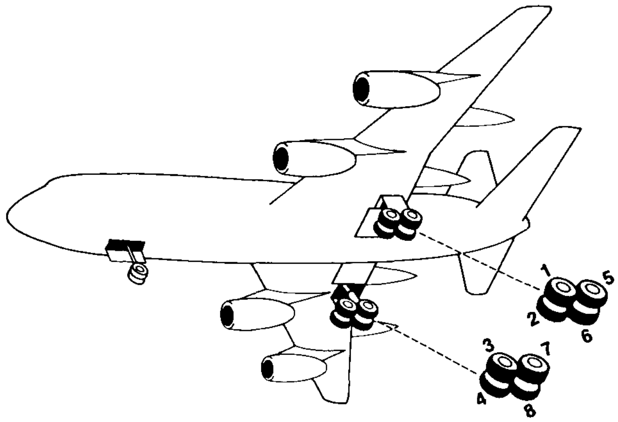


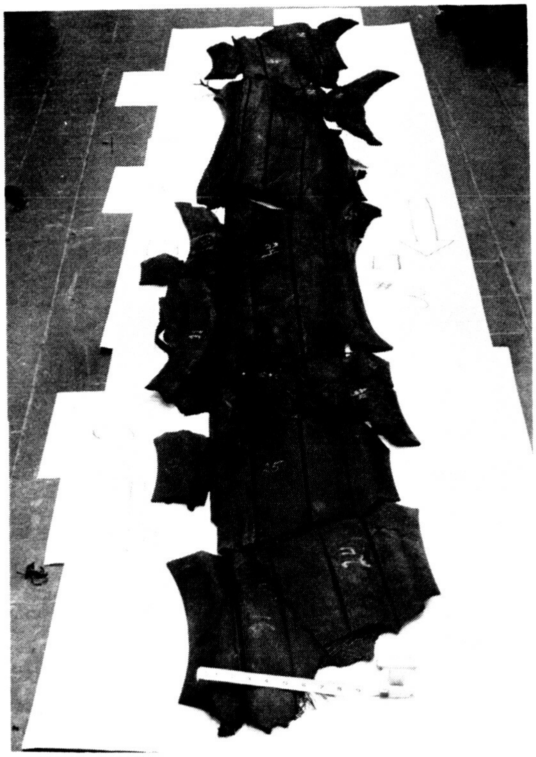
Figure 1. - Positions of tire and wheel assemblies on CV-990 main landing gear.

position was 9 years old and on its second retread. Neither NASA nor ARC have established policy relative to age and number of retread cycles (appendix B). Tires are declared serviceable by visual inspection.

Ground crew interviews established that the tires were inspected before takeoff and determined to be serviceable in accordance with ARC policy. The ground crew stated that all tire pressures were normal but were not recorded since it is not ARC policy to record tire pressure readings.

1.6.2 Tire examination. - The NASA Aircraft Accident Investigation Board collected the failed-tire fragments from the runway and pieced them together for its on-site inspection and evaluation. In addition, the Board called in Mr. Stephen N. Bobo of the U.S. Department of Transportation, Research, and Special Programs Administration, Transportation Systems Center, and Mr. George Philipoff, Thompson Aircraft Tire Corp., for help in determining the sequence and cause of the tire failures. They conducted on-site analyses and collected specimens for laboratory testing.

The on-site examinations of the assembled failed-tire fragments (such as shown in fig. 2) revealed the following information: None of the tire pieces recovered showed evidence of the classic signs of overdeflection, such as creasing of the inner liner, and no latent defects were found in any tire. Tire 3 was the first to begin fragmenting. Portions of the casing recovered from the runway still had tread rubber attached, suggesting that the failure probably originated in the casing structure. Although rubber and nylon age quite slowly under favorable conditions, some embrittlement of the materials does occur, and this might be greatly accelerated by high temperatures and exposure to the elements. Durometer hardness readings were taken at several locations on the tread of all four tires with a Shore A-Scale meter. The highest hardness readings were on tires 3 and 7, each 12 years old. Tire 4 showed evidence of considerable overheating, with sidewall material containing melted nylon, balled filaments, and hard brushy ends. Most of the exposed tire rubber exhibited the blue blush of antiozonant wax exudate, a sign of overheating. Tire 4 fragments showed the classic "X" break usually attributed to catastrophic blowout failure. No evidence of failure from foreign object damage was found.



(a) Tire 3 - left front.

(b) Tire 4 - right front.

(c) Tire 7 - left rear.

(d) Tire 8 - right rear.

Figure 2. - Assembled fragments of right main gear tires from NASA 712, found on runway 32 at March Air Force Base, California.

1.7 Meteorological Information

The official March AFB 1755 weather observation was 10,000 feet scattered, 15,000 feet scattered, estimated 20,000 feet broken; visibility, 6 miles with haze; temperature, 85 °F; dewpoint, 59 °F; wind, 310° at 4 knots; altimeter setting, 29.92 inches of mercury.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

No communications equipment difficulties were reported. Interviews with U.S. Air Force personnel indicated that air traffic control procedures at March AFB were in accordance with the FAA Air Traffic Control Handbook 7110.65 with approved U.S. Air Force waivers. Chapter 3, Section 9, of the FAA Handbook, Departure Control Instructions, states,

> Inform departing IFR ... aircraft of the following:
>
> a. Before takeoff-
>
> (1) Issue the appropriate departure control frequency and beacon code ...
>
> (2) Inform all departing IFR military turboprop/turbojet aircraft (except transport and cargo types) to change to departure control. If the local controller has departure frequency override, transmit urgent instructions on this frequency. If the override capability does not exist, transmit urgent instructions on the emergency frequency.
>
> b. After takeoff-
>
> (1) When the aircraft is about 1/2 mile beyond the runway end, instruct civil aircraft and military transport to contact departure control provided further communication with you is not required.
>
> (2) Do not request departing military turboprop/turbojet aircraft (except transport and cargo types) to make radio frequency or radar beacon changes before the aircraft reaches 2,500 feet above the surface.

The March AFB procedure that calls for departing aircraft to switch to departure control frequency before starting takeoff was applied to NASA 712.

NASA 712 was equipped with three communications radios, two VHF and one UHF. Simultaneous transmission and reception was possible on any combination of the three radios. In addition, a third VHF frequency could be preset and stored for rapid selection. The flightcrew stated that during the takeoff roll the no. 1 VHF radio was set on a discrete NASA ground crew frequency and the no. 2 VHF radio was set on departure control frequency. The tower frequency was set in the VHF preset stored position. The flightcrew indicated that the UHF radio was set on departure control frequency with "guard" frequency being monitored. The aircraft commander stated that during the RTO he switched from the no. 2 VHF radio to the UHF radio and transmitted that "NASA 712 is aborting." However, since the UHF was tuned to the Ontario departure control frequency, the tower did not hear the transmission.

1.10 Aerodrome Information

Runway 14/32 at March Air Force Base is hard surfaced, 13,300 feet long, and 300 feet wide. The runway surface was not grooved at the time of the event. The middle 75 feet are PCC and 112.5 feet on each side are asphaltic concrete. The approach end of runway 32 is at 1,490 feet m.s.l., and the departure end at 1,537 feet m.s.l. Runway 32 has an average uphill gradient of 0.004 toward the departure end. Figure 3 shows the March AFB airport layout with the 2.4-mile NASA 712 aircraft taxi route and the 1.6-mile CFR response route.

1.11 Flight Recorders

1.11.1 Cockpit voice recorder. - The aircraft was equipped with a Fairchild Model A-100 cockpit voice recorder. The tape was retrieved and the quality of the playback was normal. A transcript made at the National Transportation Safety Board's CVR laboratory is included as appendix C.

1.11.2 Flight data recorder. - The aircraft was equipped with a Fairchild Model 5424 flight data recorder, serial no. 6180. The FDR was recovered and was sent to the Safety Board's Flight Recorder Laboratory in Washington, D.C., for examination and readout of the pertinent flight record.

The recorder appeared to have been exposed to smoke only. The foil medium was removed in the normal manner, and examination disclosed no evidence of exposure to heat. All parameter and binary traces were present, and all were active with the exception of the radio binary traces, which showed no evidence of radio transmissions. The readout covered 4 minutes. The altitude information was based on the runway elevation of 1,488 feet corrected to mean sea level altitude. No corrections were made to any other parameter.

This recorder receives altitude and airspeed information from the central air data computer instead of directly from the pitot and static systems. The airspeed stylus moves mechanically by a cam instead of directly by pitot/static pressures. Below 80 knots the stylus rides "high" on the uncontrolled side of the cam since there is no set position. At some point during the takeoff acceleration the system senses a pitot buildup and moves downward toward the 80-knot point, the lowest point of stylus movement. No true speed value can be obtained until reaching this point. The stylus then starts moving upward, following the controlled side of the cam, and readings are then made of the indicated airspeed in the normal manner. The reverse is true during deceleration, with the airspeed dropping off. The stylus moves down the controlled side of the cam until it reaches the 80-knot point and then moves upward on the uncontrolled side until it reaches the "high" position.

The trace (fig. 4) indicates a steep slope moving downward from "high" to 80 knots and reversing to a peak of 143 knots. It then begins to move downward toward the 80-knot point, passes 80 knots, and begins to move upward again

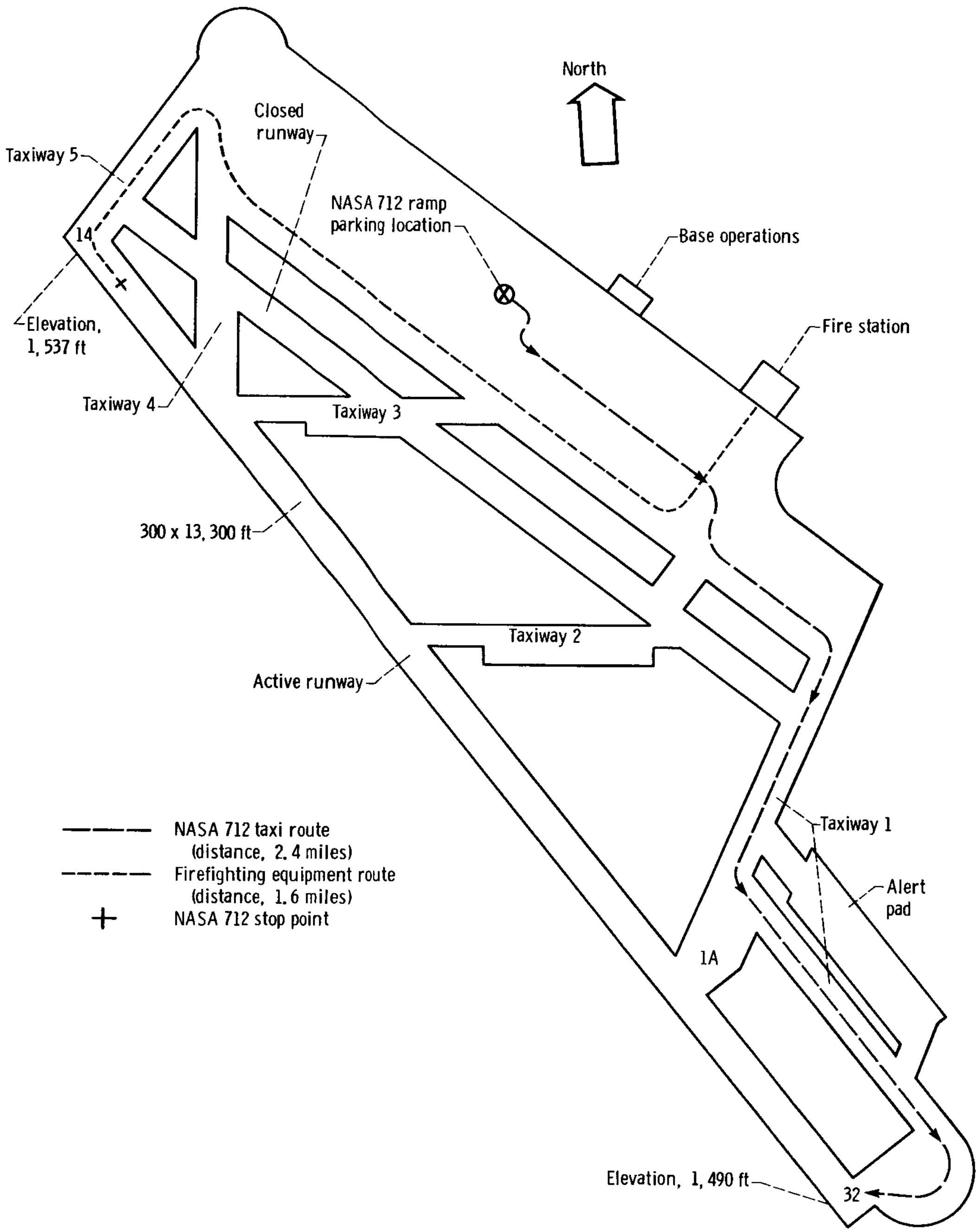


Figure 3. - Layout of March Air Force Base airport.

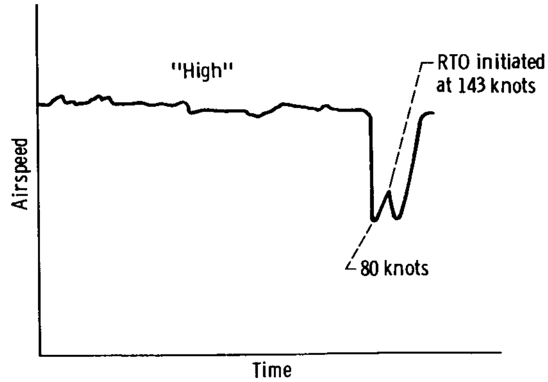


Figure 4. - Representation of indicated-airspeed trace from NASA 712 flight data recorder.

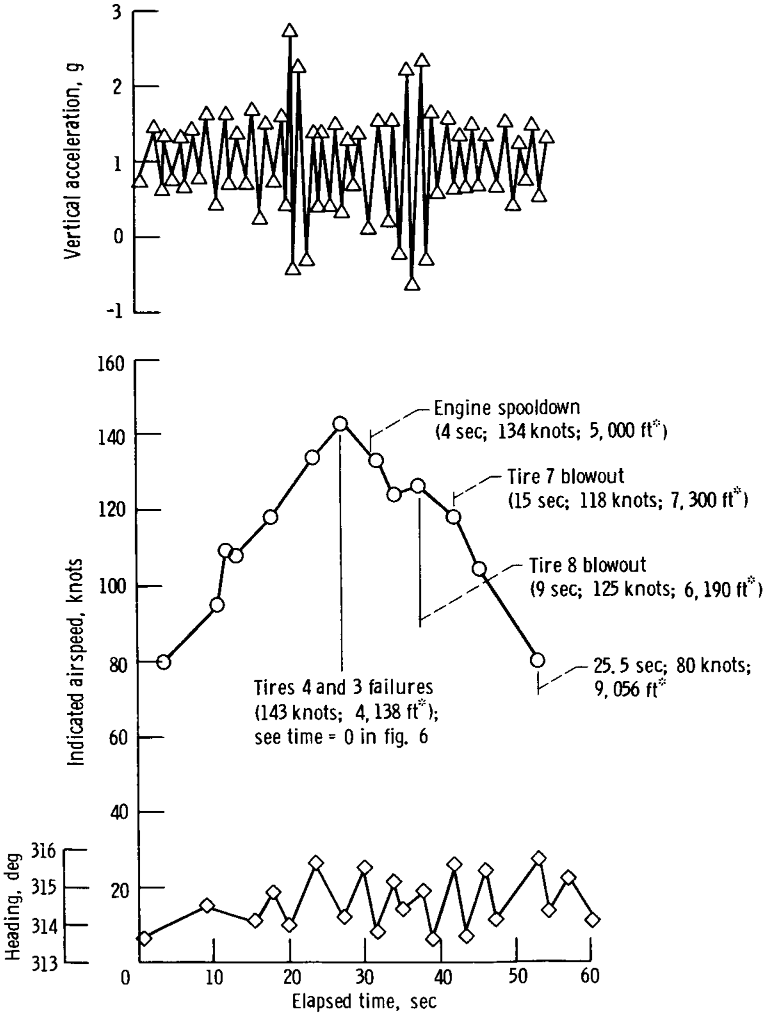


Figure 5. - Time histories of NASA 712 flight data recorder parameters during rejected takeoff. Asterisks denote distance from runway 32 threshold.

toward "high." This latter portion of the trace is not as steep as the beginning portion, indicating that deceleration was slower than acceleration. Measurements suggest that the deceleration rate during the RTO was approximately half the acceleration rate during takeoff roll. Figure 5 shows the time-history of the airspeed data as well as the vertical acceleration and aircraft heading variation during the incident.

1.12 Runway Event Reconstruction

The sequence of aircraft accident events was reconstructed by identifying the debris and its location on the runway (fig. 6) along with marks made on the runway surface primarily by the tire and wheel assemblies of the right main landing gear. Some debris had been identified, tagged, and removed from the runway surface by Air Force personnel before the NASA Aircraft Accident Investigation Board began their runway inspection. These tire and wheel fragments were made available for inspection by Board members.

The first marks found were white tire scrub marks, caused by the heavy aircraft scrubbing black deposits off the PCC runway surface, tracking from taxiway 1 onto runway 32. The width of each mark and the spacing between the marks of each landing gear were the same as the dimensions of the CV-990 aircraft (fig. 7). These white tire marks faded away as the airplane entered the moderately to heavily rubber contaminated area near the runway centerline at about 700 feet.[2] The marks did not show evidence of dragging brakes or underinflated tires. The first tire rubber shards were found at about 1,400 feet on the right side of the centerline near the arresting gear cable (fig. 6(a)). At 2,200 feet and about 11 feet right of the centerline, fresh squiggly rubber marks were found on the rubber-coated PCC surface in line with the estimated position of tires 3 and 7. These wavy intermittent rubber marks, visible for about 400 feet (fig. 8), were later associated with tire 3 by tread debris found nearby. All of the tire fragments collected on the runway between 1,300 and 4,000 feet were later identified with tire 3. Rubber marks were found on the runway surface at 4,125 and 4,138 feet, indicating where tire 4 and then tire 3 blew out. Visible score marks (fig. 9), starting at about 4,175 feet, showed where the wheel flange rims of wheels 3 and 4 contacted the PCC surface. Fragments from the remainder of tire 3 and from tire 4 were scattered over a large portion of the runway surface between 4,000 and 5,200 feet.

The wheel rim marks on the PCC surface showed the gradual right drift of the aircraft as it traveled down the runway. At about 5,665 feet the aircraft was 10 feet right of the runway centerline. Subsequent wheel marks showed a gradual turn back toward the runway centerline (fig. 6(a)). Wheel fragments from wheels 3 and 4 were found on the runway starting at about 5,600 feet. A fragment from the wheel 4 is shown in figure 10. Rubber marks on the runway surface at 6,190 feet indicated tire 8 blowout. Scuff marks on the runway surface at 7,300 feet (fig. 11) indicated tire 7 blowout. A large number of tire rubber and wheel fragments were found scattered over the runway from 7,100 to 8,400 feet.

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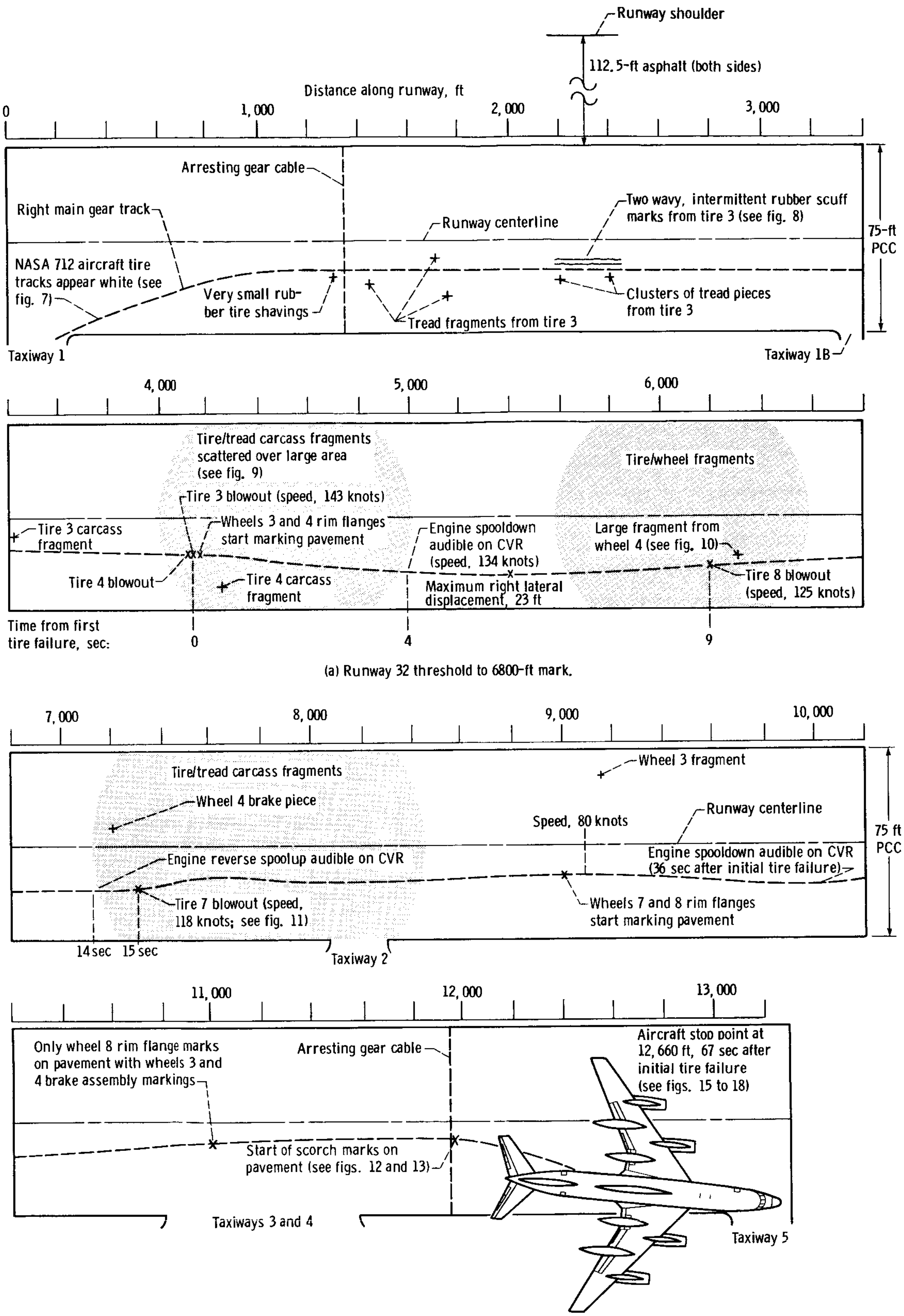
[2]All references to runway 32 distances are in feet starting at the approach/takeoff end (0 ft) and progressing to the departure end (13,300 ft).



(a) Runway 32 threshold to 6800-ft mark.

(b) 6800-ft mark to end of runway 32.

Figure 6. - Reconstruction of NASA 712 accident. Total runway width, 300 ft with 75-ft PCC surface in center and 112.5-ft asphalt on both sides.

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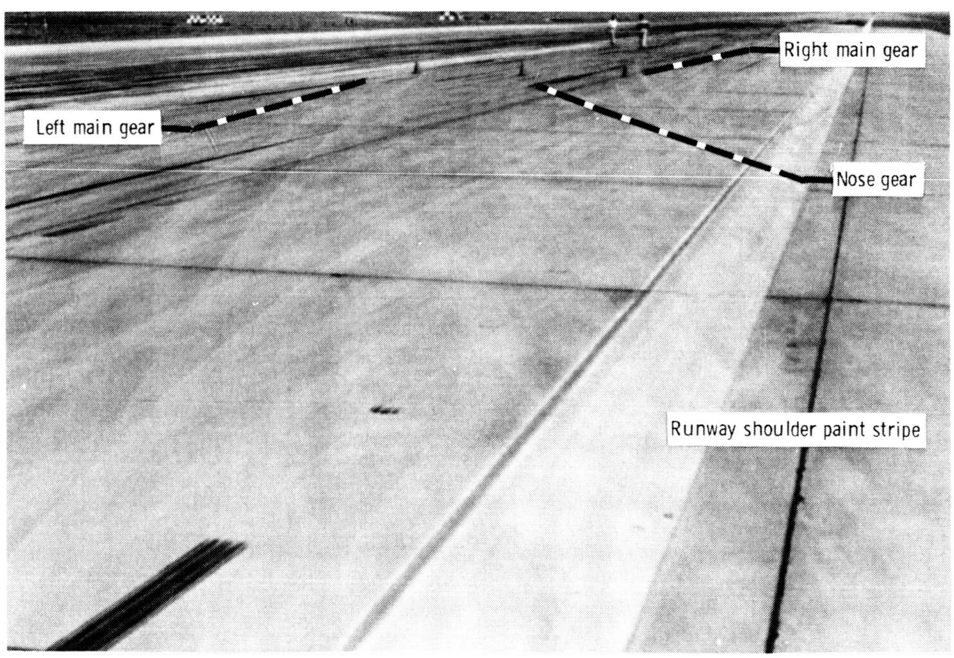
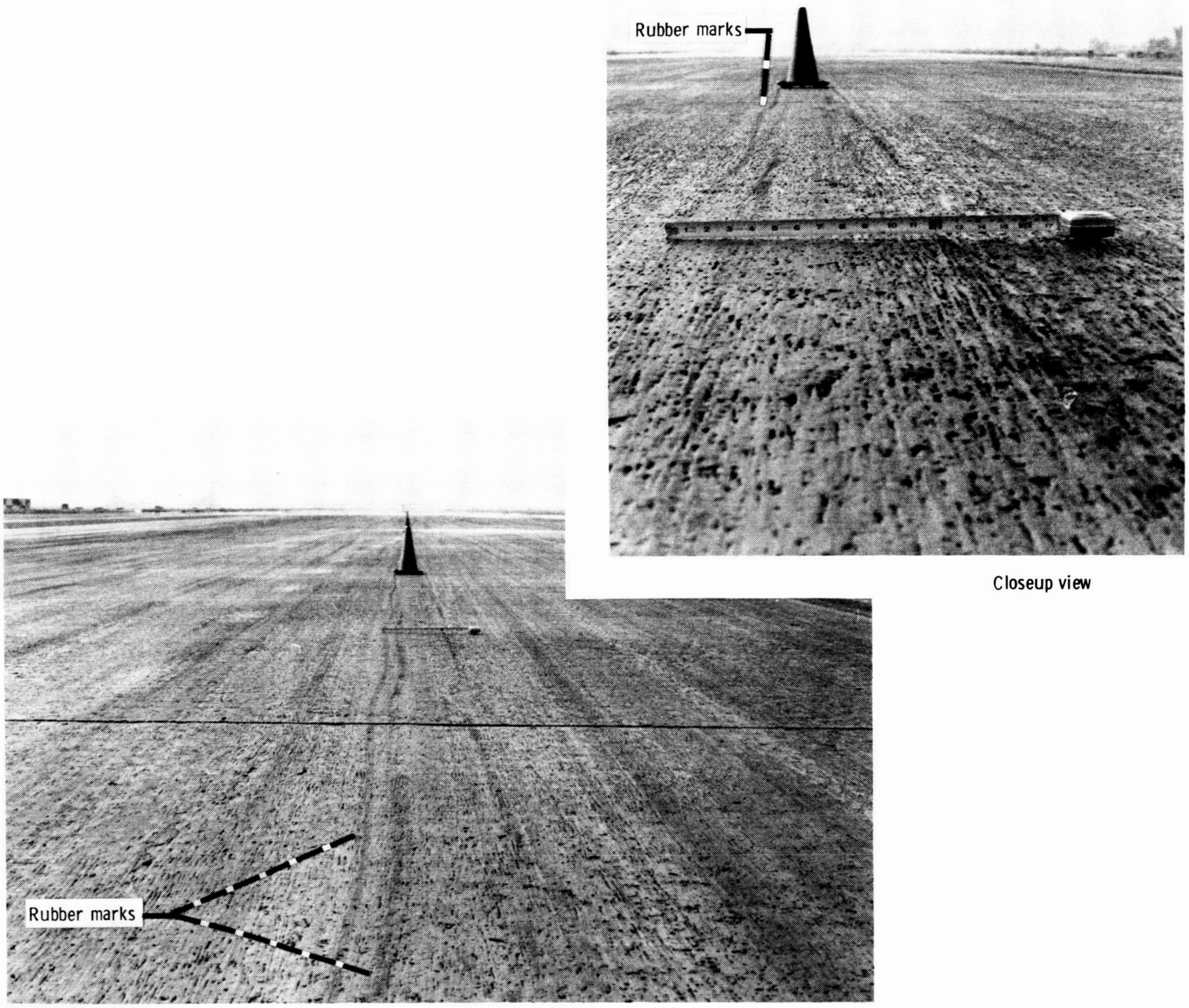
(a) On runway 32 looking back toward taxiway 1.



(b) Near runway shoulder at taxiway 1 looking toward runway 32.

Figure 7. - Suspected white tire scrub marks produced during turn onto runway 32 at taxiway 1.



Closeup view

Figure 8. - Tire 3 rubber marks found on surface 2, 200 ft from threshold of runway 32.

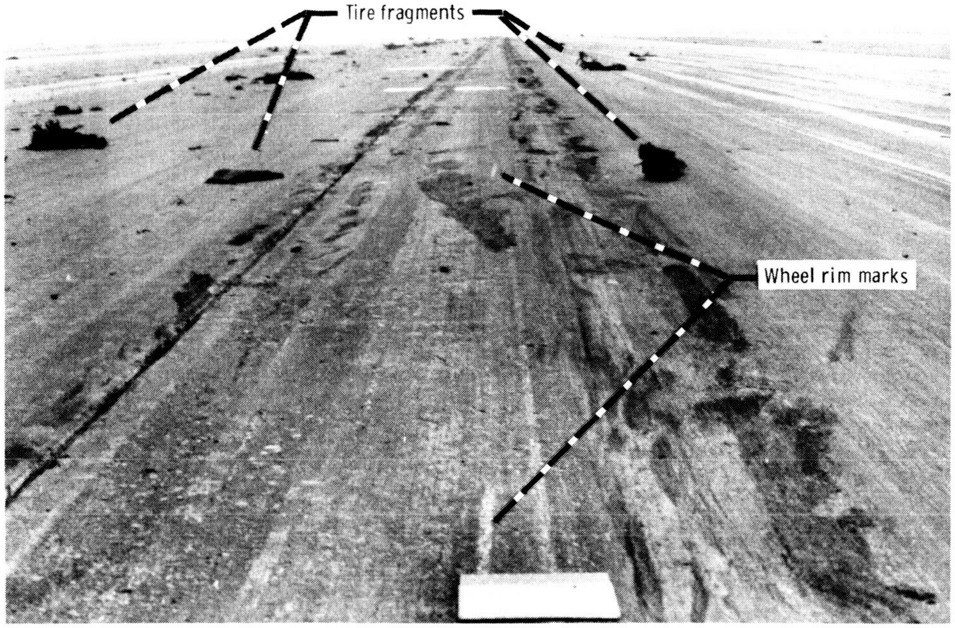


Figure 9. - Wheel flange rim marks and debris from tires 3 and 4 at approximately 4, 188 ft from runway 32 threshold.

Figure 10. - Fragment of wheel 4 found 6, 300 ft from runway 32 threshold.

Figure 11. - Runway surface rubber marks from blowout of tire 7.

Wheel scuff marks on the runway surface at 8,000 feet indicated that wheels 3 and 4 were worn down to the hub (wide marks) but that wheels 7 and 8 still retained flanges (two narrow marks for each wheel). At 9,000 feet the aircraft was on the runway centerline, and at 10,000 feet it was 6 feet right of centerline. The first evidence of fire on the runway - scorched, discolored concrete surface - was at 11,950 feet. The marks were in line with the tracks of the right main gear wheels. The scorched surface marks persisted down the runway to the aircraft stop point at 12,660 feet (figs. 12 and 13). Some additional wheel/brake assembly debris (fig. 14) was found on the runway at various locations. The aircraft wreckage on the runway was photographed from a helicopter (fig. 15) and at various ground locations (figs. 16 to 18).

1.13 Medical and Toxicological Information

1.13.1 Medical response. - The flight surgeon stated that he was notified by phone of the ground emergency at 1830. He then initiated the pyramid recall of aeromedical services. The medical team arrived at the entry control point (ECP) at 1850. The flight surgeon later assessed the crew and cabin occupants at base operations. He stated that there were no signs of incapacitation or intoxication in any of the 4 crewmembers and 15 scientists and technicians. At 2020 at the base hospital, three of the NASA crewmembers (aircraft commander, pilot, and flight engineer) were examined and statements were taken. No medical problems were noted. The crew signed permission slips, and blood and urine specimens were obtained for later toxicological analyses.

Although there were no casualties, two firefighters incurred foam burn of the eyes. Good pain relief was obtained by flushing their eyes with a saline solution. The two firefighters were then transferred from the ECP to the hospital. There were no further reports of injuries.

1.13.2 Toxicological tests. - Toxicological tests were performed on the urine and blood specimens taken from the three crewmembers by Reference Laboratory in Colton, California. These tests included radio-, fluorescent, and enzyme immunoassay and gas chromatography. All tests were negative for alcohol, carbon monoxide, opiates, cocaine, barbiturates, marijuana (THC), amphetamines, antidepressants, and phenyclidine (PCP), as well as for any other therapeutic drugs.

1.14 Fire

1.14.1 Conditions. - A aircraft right-wing fuel tank was penetrated by an object or objects from the disintegrating wheels, brakes, or tires. Damage was severe enough to cause a "basketball-sized" column of fuel to pour from a right-wing fuel tank about 7 to 9 feet forward and inboard of the right main landing gear.

Witnesses stated that there was fire under the right wing in the area of the right main gear before the aircraft came to a stop, but their estimates of where the fire began along the aircraft deceleration path varied. However, no witnesses stated that they saw evidence of fire before 7,000 feet. Technicians seated on the right side of the aircraft cabin observed fluid on the windows and wetness on the right-wing inboard antishock body before they observed flames emanating from under the inboard trailing edge of the right wing (at about 10,000 ft).

Figure 12. - Runway surface scorch marks and tire rubber debris from right main gear at about 11, 950 ft down runway 32.

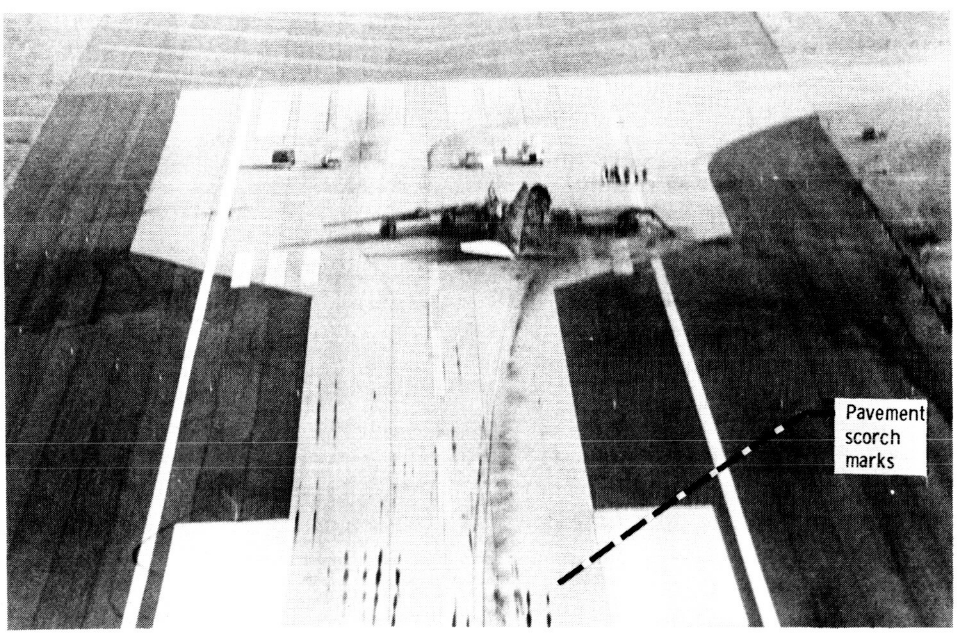
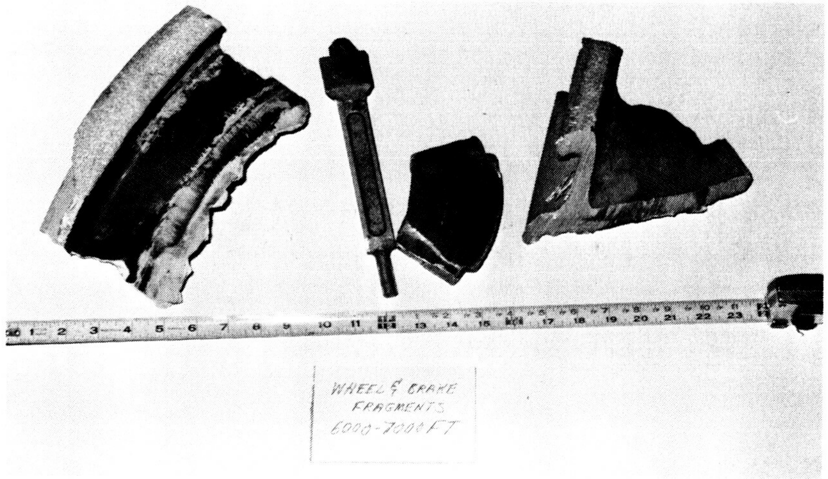
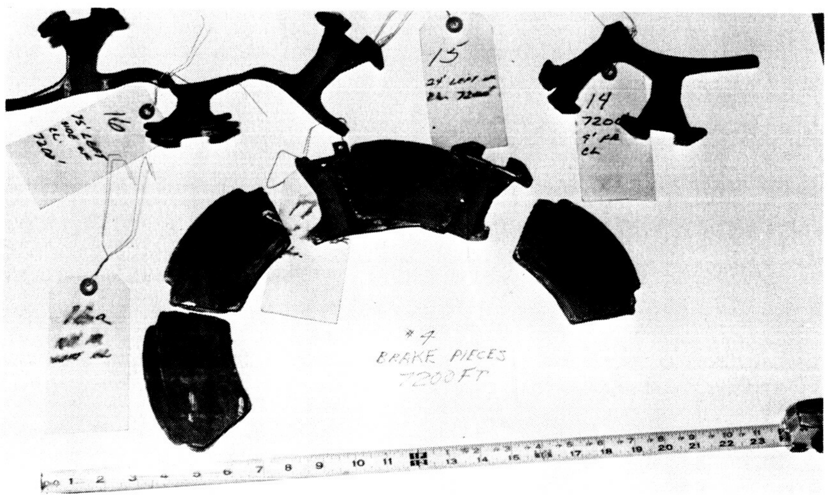


Figure 13. - Aerial view of fire-damaged NASA 712 at stop point, 12, 660 ft down runway 32.



(a) Found between 6, 000 and 7, 000 ft down runway 32.



(b) Found nearly 7, 200 ft down runway 32.

(c) Found between 10, 000 and 11, 000 ft down runway 32.

Figure 14. - Some additional fragments of right main gear wheel/brake assembly found at various locations on runway.

Figure 15. - Aerial view of fire-damaged NASA 712 taken at front of wreckage.

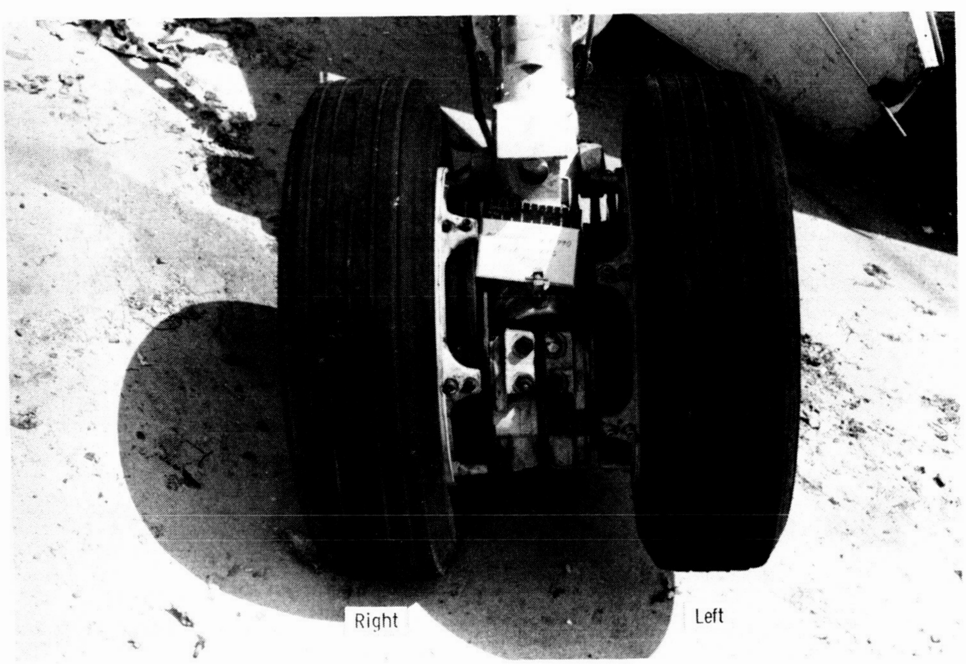


Figure 16. - Closeup view of nose gear tires.

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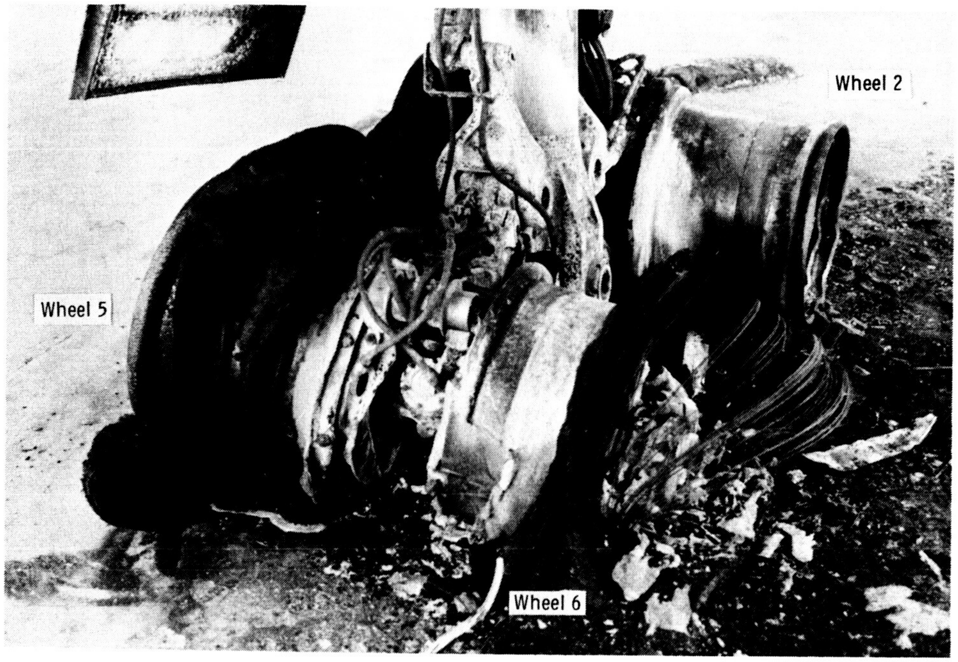

Figure 17. - Closeup view of left main gear wheels.

Figure 18. - Closeup view of right main gear wheels after fire.

The fire became more intense after the aircraft came to a stop and the fuel column became involved. The fire rapidly spread to the right inboard engine, to the right-wing root, and then rearward along the right fuselage, engulfing the right side of the aircraft in flames (figs. 19 and 20).

1.14.2 CFR response. - The tower controller activated the primary crash network at 1809:49[3]; all parties were on the network at 1809:59, including the fire department alarm room operator.[4] The tower controller completed transmitting the required information format at 1810:28. The alarm room operator stayed on-line while questions were answered and secured the primary crash network telephone at 1810:51. At 1810:45 base operations activated the secondary crash network, which was answered by the alarm room operator at 1810:55. After hanging up the secondary crash network telephone, he alerted fire department personnel via the public address system at 1811:50. A number of firemen were already moving toward their vehicles 10 to 15 seconds before his announcement as a result of a visual sighting and notification by a fireman standing in front of the fire station. All available firefighters and seven pieces of CFR equipment, including three major fire-fighting vehicles, responded.

Chief 1 called "in service" at 1812:15 and arrived on the scene at 1813:53. Enroute, Chief 1 gave orders to recall all off-duty firemen, to request mutual aid support, and to set up resupply near the departure end of runway 32 and the aircraft wreckage. The first crash vehicle (P-2) was applying aqueous film-forming foam (AFFF) on the aircraft fire at 1814:24. The second P-2 was applying AFFF at 1814:53, and the fire truck (P-15) arrived on the scene at 1815:48. The first and second P-2's and the P-15 were applying AFFF in 3 minutes and 56 seconds, 4 minutes and 25 seconds, and 5 minutes and 20 seconds, respectively, after the alarm room was notified of the emergency through the primary crash network.

March AFB CFR equipment and response is directed to providing time for rescue and not to extinguishing massive aircraft fires. Since personnel rescue was not required, firefighting efforts were directed toward extinguishing the fire in the right wing and the fuselage. All available equipment was dispatched to the site or to the three resupply points, as appropriate. Aqueous film-forming foam in a 3 percent concentrate, meeting Military Specification F-243-85C, was applied. During the firefighting, 1,915 gallons of AFFF and 59,000 gallons of water were expended. According to witnesses the foaming agent retarded the fire when applied, but the quantity was insufficient to put out the fire. The fire abated as the aircraft fuel supply was exhausted. Table I summarizes the transmissions related to CFR activities in response to the accident.

1.14.3 Security response. - The security flight chief on duty stated that he received notification of a ground emergency via the primary crash network at 1812. He proceeded to the area and at 1813 established initial entry control points (ECP) at taxiway 1 and taxiway 5. The ECP allows only authorized personnel such as the fire department, emergency vehicles, base commander, and security personnel into the crash area. The security response team set up

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[3]This time is a normalized time using fire department tapes, tower tapes, and a correlation with Greenwich mean time.

[4]The alarm room operator on duty at the time of the accident was a relief operator. His normal assignment was as a CFR vehicle driver.

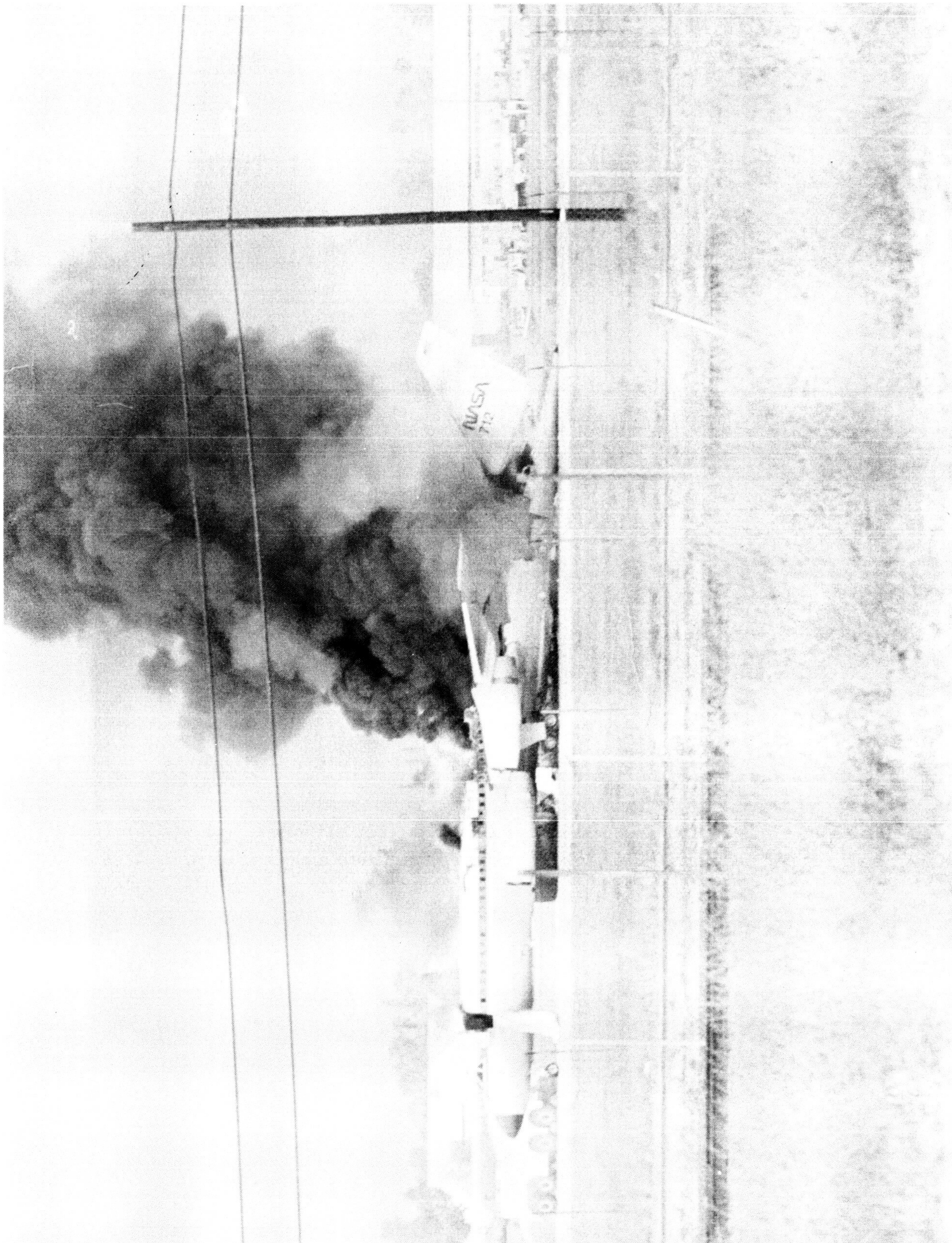

Figure 19. - NASA 712 on fire at end of runway 32.

Figure 20. - NASA 712 engulfed in flames.

TABLE I. - CHRONOLOGICAL SUMMARY OF MARCH AFB CFR/TOWER TRANSCRIPT

Normalized time (local), min: sec	Event	Normalized time (local), min: sec	Event
1806:22	Tower clears NASA 712 to hold	1812:04	"Crash Control, March tower, aircraft is sitting on departure end and looks like he is on fire."
1806:25	NASA 712 acknowledges	1812:15	"Alarm, Chief 1, 10-10-10."
1808:06	Tower issues takeoff clearance	1812:39	Tower inquires about about CFR response delay
1808:15	NASA 712 acknowledges	1812:44	"Rescue 5 in service." (P-10)
1809:09	Tower tells Ontario departure control that NASA 712 is departing	1812:45	"OK, they're getting the response message now."
1809:30	NASA 712 calls abort on Ontario departure control frequency	1812:54	Chief 1 begins recall; requests mutual aid
1809:34	Tower asks if NASA 712 is experiencing difficulties	1812:59	"10-4, Chief 1."
1809:49	Tower activates primary crash network (alarm room operator picks up phone)	1813:02	"Crash 3 in service."
1809:59	All parties are on crash network	1813:06	Chief 1 tells alarm room room to have base supply set up
1810:03-1810:28	Tower announces emergency details	1813:23	Chief 1 tells engine 7 (P-12) to set up resupply
1810:28	Tower answers questions	1813:53	Chief 1 on scene
1810:45	Base operations activates secondary crash network	1814:24	Crash 2 (P-2) spraying agent
1810:51	Alarm room operator secures primary crash network	1814:53	Crash 1 (P-2) spraying agent
1810:55	Alarm room operator picks up secondary crash network	1815:48	Crash 3 (P-15) on scene
1811:50	Alarm room operator secures secondary crash network and announces fire by public address system		

a 2,000-foot perimeter. By 1825, the evacuation of nonessential personnel was complete, and at 1831 the on-scene commander assumed duties.

1.15 Survival Aspects

1.15.1 Aircraft information. - NASA 712 was equipped with four evacuation slides, two overwing window exits, and two cockpit escape ropes. The evacuation slides were located at the forward and rear doors on both sides of the airplane. These inflatable escape slides were manufactured by Air Cruisers Company and had been inspected within the past year. The evacuation slide inflation system consisted of a spring-loaded container mounted on a door panel actuated by a lanyard-pulled pin as the door panel was lowered to the floor.

The aircraft fire protection system consisted of two subsystems - fire detection and fire extinguishing. Overheat/fire sensors in the engine areas activated cockpit warning bells and lights. Dual lights in each plastic fire-pull handle, one for each engine, on the fire control panel illuminated to indicate overheat or fire - flashing illumination for overheat conditions and steady illumination for fire conditions. When pulled, this handle shut off the fluid supply to the selected engine area and exposed normally inaccessible extinguishing agent release switches for each engine nacelle area. One spring-clipped access door on the left side of each engine nacelle allowed ground access for fighting engine fires with a portable fire extinguisher. Heat-sensing thermoswitches in the main wheel wells also actuated the bell and illuminated corresponding lights. There was no provision for the ground introduction of a fire-extinguishing agent in the wheel well areas.

1.15.2 Passenger preparedness. - A CV-990 mission director's preflight briefing and a CV-990 safety briefing are normally given before takeoff. As most of the scientists and technicians onboard had previously flown on the CV-990, no general safety briefings were given before this mission. However, the two scientists who had never flown on NASA 712 were given a safety briefing about 30 to 40 minutes before the flight. Most of the scientists and technicians onboard concurred that the safety briefings they had received were adequate. However, there was some difference of opinion as to whether the passengers could deploy the evacuation slides if necessary, and there was some confusion over whether the slides were armed during takeoff. In addition, they stated that there was no specific training given regarding procedures after evacuating the airplane.

The four crewmembers were wearing Nomex flight suits. However, there is no current NASA requirement for other onboard aircraft personnel to wear fire-retardant flight suits during missions; only 3 of the 15 scientists and technicians in the cabin were wearing them. Witnesses stated that previous attempts by some of the scientists and technicians to obtain fire-retardant flight suits were not successful.

1.15.3 Aircraft evacuation. - The flightcrew and the cabin occupants evacuated by the forward and aft door slides on the left side of the aircraft. The four crewmembers, the mission manager, and eight scientists and technicians exited by the forward door slide; six scientists and technicians exited by the aft door slide. All agreed that the evacuation was accomplished in approximately 30 to 45 seconds and characterized personnel conduct as calm.

No specific individuals were formally designated to deploy the various emergency evacuation devices, but it was generally understood that the mission manager or his assistant would normally deploy the front door slides and the nearest technician seated in the back would deploy the aft slides. No specific command was given to the scientists and technicians by the flightcrew or the mission manager to evacuate the airplane, and no direction was given as to which evacuation devices to use. However, the left forward and left aft door slides were deployed in a timely manner by Northrop technicians who were seated near the doors and had flown frequently on the CV-990. Witness testimony indicated that the forward door slide did not deploy automatically when the door was opened. The Northrop technician stated that he manually "threw the slide out the door" and then it inflated.

1.16 Additional Information

1.16.1 RTO accident/incident information. - In 1977 a Federal Aviation Administration (FAA) report[5] covering 171 RTO's from 1964 to 1975 concluded that 87 percent had resulted from some failure or malfunction of tires, wheels, or brakes - 74 percent from tires alone. The data revealed that engine failures have not been the dominant causal factor for some time. The NASA Aircraft Accident Investigation Board collected data on RTO accidents and incidents since 1975, when the FAA study ended, to determine if these trends continued. Sixty-one accident/incident records covering January 1976 to September 1985 were identified from National Transportation Safety Board, FAA, British Civil Aviation Authority, and NASA Aviation Safety Reporting System sources. The dominant cause, accounting for 34 percent of the documented cases, was tire/wheel failure. The second most dominant cause, accounting for 23 percent, was engine failure or malfunction. A variety of factors contributed to the remaining 43 percent of the cases. Hence the trend appears to be continuing that engine failures are not the primary cause of aircraft rejected-takeoff accidents/incidents.

Additional information from the Douglas Aircraft Company on a limited number of DC-10 tire-related accidents/incidents indicates that aircraft damage and injury rates are substantially higher if a pilot rejects rather than continues takeoff when faced with tire malfunction at speeds near V_1.

1.16.2 Rejected-takeoff procedures. - The Emergency Procedures section of the ARC CV-990 Operating Manual includes rejected-takeoff procedures from the American Airlines CV-990 Operating Manual and the Convair Flight Manual.

ENGINE FAILURE, FIRE OR OVERHEAT WARNING DURING TAKEOFF
(American Airlines)

(1) DECISION TO REJECT OR CONTINUE TAKEOFF - If trouble occurs before reaching V_1, abort takeoff; if speed is above V_1, takeoff should be continued. If takeoff is aborted, retard all throttles, apply brakes, pull speed brake handle full aft, and use reverse thrust as required. If runway is slippery, be alert to directional control difficulty when reversing with an engine out; use symmetrical reverse thrust to the extent stopping requirement permits.

(2) ENGINE POWER ...

TAKEOFF ABORT

(Convair)

(1) BEFORE V_1 - Abort performance is based on immediate throttle retardation and brake application followed by spoilers as soon as possible.

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[5]Jet Transport Rejected Takeoffs, Final Report, February 1977, Flight Standards Service, Federal Aviation Administration.

(2) REVERSE THRUST - The use of reverse thrust is important especially on a wet runway. It must be applied with caution. If the abort was due to an engine failure, only the symmetrical engines should be reversed. Do not let this choice delay brake and spoiler application.

(3) BRAKES - Use maximum brake application to obtain full antiskid braking. Release and reapply only when in a positive skid or drift.

These procedures are general and do not address specific actions, cautions, or hazards (i.e., directional control, brake failure, rim failure, antiskid anomalies, etc.) associated with RTO's after blown tires.

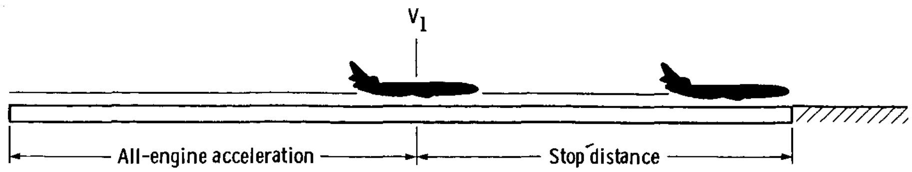
Discussions with training personnel from the major air carriers indicate that procedures for RTO's have been standardized. The consensus of the procedures is that once a decision to abort has been made the following steps should be taken:

(1) Set throttles to idle and simultaneously depress brake pedals fully.
(2) Maintain directional control.
(3) Extend spoilers.
(4) Reverse thrust.
(5) Put forward pressure (as required) on control column.
(6) Maintain maximum braking until aircraft stops.

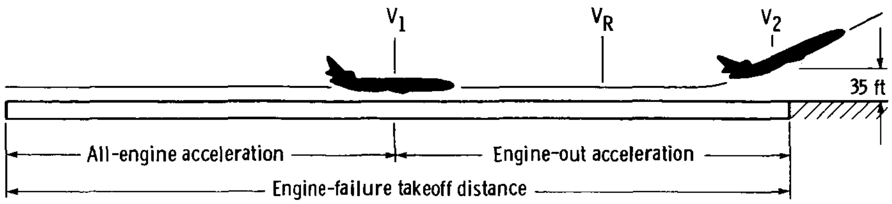
The air carriers' training philosophy is not to change the RTO procedure to meet different emergency situations. The rationale is that having one procedure for all situations makes it easier to train flightcrews and may significantly reduce flightcrew reaction time to an emergency.

1.16.3 Pilot training for rejected takeoffs. - The determination of the minimum runway length required for takeoff, or conversely, the determination of the maximum weight that an airplane could take off any given runway is based on what is called a balanced-field concept (fig. 21). This concept is predicated on the calculated ability of the aircraft either to stop within the runway length or to successfully continue to take off after an engine failure during the takeoff roll. The speed at which the decision must be made either to continue or to reject takeoff is referred to as V_1. This speed is the most critical factor affecting the pilot's decision to reject or continue a takeoff. If an engine failure occurs before reaching V_1 on takeoff, the capability exists to stop the aircraft on a smooth, dry, hard-surface runway by using wheel brakes alone without reverse thrust. Decision speed V_1 is predicated on having normal brakes, wheels, and tires. If an engine failure occurs at or above V_1, the takeoff may be continued and the pilot, using proper procedures and techniques, is assured of achieving a 35-foot height over the runway end.

Appendix E (Flight Training Requirements) of 14 CFR 121 requires that air carrier flightcrews receive appropriate initial, transition, and upgraded training. This training must include takeoff training with a simulated failure of the most critical engine, which may be accomplished in a visual simulator. In general, RTO training has been predicated on an engine failure before reaching the calculated V_1 speed for the aircraft gross weight, atmospheric conditions, and field elevation. However, there is no requirement to familiarize pilots with the effect of blown tires on braking or with directional con-



(a) All-engine-acceleration stop.



(b) Engine-failure takeoff.

Figure 21. - Balanced-field-length takeoff.

trol and antiskid anomalies or to identify hazards associated with heavy aircraft rolling at high speeds on blown tires and frangible rims.

After surveying air carrier flight training simulator facilities, the Board found that 76 simulators in operation at 16 air carriers as of October 1985 met FAA Phase II or Phase III requirements. These Phase II/III simulators can present failed-tire models with varying degrees of realism. Several air carriers, however, reported that pilots are exposed to simulated failed-tire aircraft operations only during transition training from one type of aircraft to another and not during regular currency training.

1.16.4 Nose wheel steering. - The CV-990 Operating Manual, under normal operating procedures for takeoff, states that "...To obtain maximum airplane acceleration (and directional control...), hold nose wheel on runway as long as possible. Nose wheel steering should normally be used for directional control until airspeed has increased to 80 knots. The rudder becomes effective ... and should normally be used for directional control at higher airspeeds." Landing procedures include the following: "...On touchdown release backpressure on the control column as soon as the main wheels touch the runway, gradually lowering the nose wheel to the runway. As soon as the nose wheel touches, hold forward pressure on yoke..." A survey of checklists for other transport aircraft indicates similar procedures.

1.16.5 Antiskid brake system operation. - The CV-990 antiskid brake system is a fully automatic, pressure-modulating, wheel-braking system, controlled by individual wheel speed transducers, an antiskid control box, and individual antiskid control valves for each main wheel brake. The antiskid function does not operate until the aircraft wheels rotate or, on landing, until one of the two ground safety relays indicates ground mode or the protected wheel spins up. The antiskid logic system uses the fastest of the eight main wheels as the primary reference. Any wheel or wheels that deviate a preset percentage from this reference wheel speed are sensed as being in a skid. A release signal is transmitted to that wheel's antiskid control valve. Brake pressure is reapplied automatically when that wheel attains a speed value within a specified percentage of the reference wheel's speed. For the antiskid brake system to modulate pressure properly, the individual wheel speeds (and the airplane's ground speed) must be above the low-speed dropout value of 10 knots and within 30-percent agreement in individual wheel speeds. If these wheel speeds exceed a 30-percent differential, a locked-wheel (brake release) situation would occur rather than the normal brake-pressure-modulated antiskid response. In this accident the nearly simultaneous failure of tires 3 and 4 resulted in greater than 30-percent speed difference between wheels 3 and 4 (blown tires, smaller diameters, higher speeds) and the other six main gear tires. As a consequence, deflection of only the left brake pedal would result in no braking. Hydro-Aire engineers stated that under these nonuniform wheel speed conditions maximum deflection of both pedals would result in one of the following scenarios:

(1) Brake pressure would be applied only to the fast wheels (nos. 3 and 4), promptly (1 to 2 sec) reducing the speed differential. Once the wheel speeds were within 30 percent of each other, the system would return to normal, fully modulated, individual-wheel-control antiskid braking.

(2) The wheel or wheels without tires would fully lock and remain locked, flat spotting the rim or rims.

(3) The wheel or wheels without tires would spin down, generate a locked-wheel release, spin back up to freewheeling speed, and then repeat this cycle. In this scenario the six normal main wheel brakes would remain fully released.

2.0 ANALYSIS

2.1 General

The flightcrew was properly certified, and each crewmember had received the training and rest prescribed by applicable ARC policies. There was no evidence of medical problems that might have affected their performance.

The aircraft was certified airworthy in accordance with ARC airworthiness procedures. It was maintained in accordance with Convair recommended maintenance procedures. The aircraft gross weight and center of gravity were within prescribed limits. The aircraft's airframe, systems, and powerplants were not causal to this accident.

2.2 Accident Sequence

NASA 712 taxied the 2.4-mile taxi route in about 5 minutes (average speed of 28.8 mph, or 25 knots). Aircraft tire roll tests have indicated that the taxi out for takeoff with a heavily loaded aircraft can greatly stress the tires and produce significant heat buildup. Taxi techniques can influence the amount of heat built up by sidewall flexing. Because of the low heat conductivity of rubber, tire temperatures continue to rise with distance traveled. As this temperature rise is also influenced by taxi speed, pilots should not increase the taxi speed when the taxi distance is long. Because higher tire temperatures decrease tire strength, the FAA and airframe manufacturers recommend a maximum taxi speed of not more than 30 knots. Lower taxi speeds should be used at high gross weights or for long taxi distances. The Board concluded that excessive taxi speed was not a contributing factor in this accident since the average taxi speed of NASA 712 was about 25 knots.

The flightcrew and the scientists and technicians onboard the aircraft stated that the taxi out was normal, with the exception of a "thump" heard when the aircraft was on the taxiway. After discussing the thump, the occupants concluded that it was probably caused by the air-conditioning ducting, since the same sound had been heard on previous flights. The Board examined the taxi route surface and found nothing that could account for the thump.

NASA 712 left a distinctive white track as it took the runway. The aircraft tires scrubbed black jet engine exhaust deposits off the PCC runway surface during the turn onto the runway. The width of the individual tire tread was uniform, showing no evidence of lost inflation pressure or other tire abnormality. Light or even moderate brake drag probably would not be detected on the runway or taxiway surface, but subsequent heat effects would have occurred in the tire body. The tire 3 retread cap, most of which was recovered, showed no heat effects. Inspection of the wheel bearings on the right main landing gear, with particular emphasis on bearings 3 and 4, revealed no abnormalities. An inspection of the brakes, although not conclusive because of fire damage, showed no evidence of dragging. Therefore the Board concludes that the main gear tires were properly inflated and that the brake systems were normal when the aircraft taxied onto the runway.

The CV-990 aircraft has dual nose wheels and eight main gear tires mounted on two four-wheel trucks. Each main gear truck has two axles, one fore and one aft of the landing gear strut. The design allows vertical but not lateral pivoting of the truck. Consequently a failure of one of the tires results in that load being shifted to the remaining tire on the same axle.

The evidence showed that the accident began with tread/carcass separation on tire 3, precipitating the overload failure of tire 4 since both tires were on the same axle. The analysis of tire and wheel marks on the runway indicated that the failure sequence began when the tread from the tire 3 started coming apart at about 1,400 feet. The failing tire 3 caused tire 4 to run in an overloaded condition. This continued until the 4,125-foot mark when tire 4 blew, followed 0.05 second later by the blowout of the tire 3 carcass at 4,138 feet. The postaccident examination of the tire fragments indicated that extreme heat had built up in tire 4, contributing to its failure.

With the failure of tires 3 and 4 on the right truck, nos. 3 and 4 frangible aluminum wheels contacted the runway. The right side of the aircraft was now supported by tires 7 and 8 and wheel rims 3 and 4. The aircraft began riding intermittently on wheel rims 3 and 4 from the 4,175-foot point. Most of the remaining rubber of tires 3 and 4 (except for the bead bundles) was abraded very quickly. The black scuffing on the runway from these tire remnants and bead bundles, and the subsequent failure of tires 7 and 8 probably caused an almost continuous trail of white smoke to be emitted from the underside of the aircraft.

The drag resulting from the tire failures caused the aircraft to swerve slightly to the right. Marks on the runway indicated that the swerve began within 300 feet (less than 2 sec) of the first two tire blowouts. There were no visible indications of left main gear wheel braking to correct for this swerve and, in fact, the pilot stated that he was "going to stay off the brakes." The actions taken by the pilot, after the first tire blowouts, were to close the throttles (the CVR indicated that the throttles were closed within 4 seconds of these blowouts), to deploy the spoilers, and to correct for a slight right swerve.

Runway scuff marks show that tire 8 failed at 6,190 feet. From CVR information this occurred 9 seconds after tire 4 blew out. The flightcrew perceived this as the second tire failure. Tire 7 blew out at 7,300 feet and the sound was recorded on the CVR. However, the flightcrew stated that they did not hear the blowout as it was masked by the sounds of engine spoolup as reverse thrust was being applied 12 seconds after the "abort" callout. There was no runway evidence of wheel braking from either the fully operational left main gear or the failing right main gear.

After the blowouts of tires 3 and 4, rim markings were evident on the runway for approximately 1,500 feet, at which point the rims started breaking up and fragments were thrown in all directions. These fragments may have contributed to the failure of the two rear tires. From witness testimony it is suspected that the wing was punctured after failure of the nos. 3 and 4 rims and wheels, somewhere between 6,000 and 7,000 feet from the takeoff end of the runway. Outside witnesses described intermittent flashes of fire around the right main gear after 7,000 feet. Inside witnesses saw flames coming from under the right-wing flaps at 10,000 feet and passed this information to the flightcrew. The aircraft was immediately brought to a stop and evacuated. Shortly thereafter the aircraft was engulfed in flames.

2.3 Tire Failure Analysis

The sequence of tire failures was established by the marks on the runway and analyses of the tire/wheel assembly fragments. Tire 3 was the first tire to begin fragmenting. Portions of the tread recovered from the runway still had casing attached, indicating that failure probably originated in the casing structure. Once portions of the tread were lost, the diameter of the tire was reduced, causing tire 4 to run in an overloaded condition. This resulted in excessive sidewall flexing and significant heat buildup. The heating reduced cord strength and raised internal tire pressure. When the tensile limits of the cord were exceeded, a catastrophic blowout occurred. Postaccident examination of tire 4 fragments revealed evidence of extreme heat buildup as well as the classic "X" rupture usually attributed to blowout failure. Tires 7 and 8 probably failed from overload caused by the failure of tires 3 and 4. Tires 7 and 8 may also have been punctured by wheel fragments from the two forward wheel assemblies.

Tires 3, 4, and 7 were 12 years old. Although rubber and nylon age quite slowly under favorable conditions, embrittlement may be greatly accelerated by high temperatures and exposure to the elements. The degradation in physical properties of the materials due to aging may manifest itself under critical operating conditions. The Board concludes therefore that the age of the tires may have had a contributory role in this accident.

2.4 Wing Penetration

The exact moment, object, and location of penetration of the right-wing fuel tank could not be determined. Occupants seated aft in the cabin observed fluid on the right windows and the right inboard antishock body before noticing intermittent flames coming from under the trailing edge of the right inboard flap at about 10,000 feet. The fuel mist created by the tank rupture was probably mixed with the white smoke from abrading residual tire rubber and from the wheel rims scoring the PCC surface. The mist would not be discernible to the outside witnesses. A number of witnesses, including CV-990 aircraft maintenance personnel, first observed fire between 7,000 and 8,000 feet. This is coincidental to the first sounds of reverse thrust spoolup as recorded on the CVR, which occurred at about 7,150 feet, 1.5 seconds before tire 7 blew out at 7,300 feet. Aircraft forward velocity probably prevented ignition of the fuel mist until reverse thrust application disrupted the airflow around the wing and fuselage. The Board concludes that the escaping fuel mist ignited with application of reverse thrust and that a right-wing fuel tank had been penetrated before this point (7,000 feet).

The object that penetrated the wing could not be positively identified. Fire completely destroyed the right wing, leaving no clues. A careful inspection of the melted remains failed to reveal any information concerning the puncture mechanism. The CVR was electronically expanded and scrutinized for unusual signatures that might indicate the time of wing impact, but none were identified. Evidence suggests two possibilities: that the wing was penetrated by a large piece (23 lb) of tire 4 at the instant of blowout, or that the wing was ruptured by metal fragments from the disintegrating wheel and brake assemblies. Witnesses stated that the location of the penetration was forward and inboard of the right main gear near a 12-inch by 22-inch wing-fuel-tank inspection panel. Convair and NASA analyses tend to discount the possibility of wing penetration by the tire piece (appendix D).

2.5 Rejected-Takeoff Decision-Making

The most critical element of the accident was the pilot's response to the first tire failures, which occurred just before the aircraft reached V_1. At the failure moment the pilot had two options: to continue the takeoff, or to reject it. The option to continue the takeoff was a viable possibility. In fact, statistics have shown that aircraft that experience blown tires on takeoff, continue the takeoff, and land after decreasing the aircraft gross weight have incurred much less damage than those involved in RTO's. Furthermore there have been no injuries involved in those instances where takeoff was continued, but there have been fatalities and severe injuries in RTO accidents. In this accident, if the aircraft had taken off successfully, it would have averted a high-speed, heavyweight RTO. However, continuing the takeoff would have involved other factors and pilot decisions in order to maneuver and configure the aircraft to successfully terminate the flight. The Board cannot say conclusively that continuing the takeoff would have been a better option, only that statistics indicate that the potential for a successful outcome could have been greater.

Pilot testimony and CVR evidence show that the decisions of the aircraft commander and the pilot to reject the takeoff were immediate and simultaneous. The Board believes the decisions were based on their training and experience. Each pilot had over 7,000 flying hours. Written procedures and pilot training have traditionally emphasized and required that an RTO be initiated for an engine failure occurring before V_1 with the balanced-field stopping distance predicated on operable tires, wheels, and brakes. The basic RTO guideline has been to reject the takeoff if any problem is recognized before V_1 or to continue the takeoff if it is recognized at or after V_1. Since V_1 speed is the go/no-go decision speed in the event of an engine failure, the Board believes that pilots have come to regard V_1 as the go/no-go decision speed for any recognized anomaly during the takeoff roll regardless of specific factors. These factors may include conditions similar to those of this accident such as all engines operative and runway length in excess of that required for a balanced field. Statistics indicate that RTO's in response to tire problems are four times more likely to result in an accident or incident than those in response to engine problems. Therefore the Board examined pilot decision-making for rejected takeoffs.

In general, the pilot decision-making process requires two kinds of information, current and background, and this information must be integrated and acted on in seconds. Pilots should be aware that the need for an RTO can occur on every takeoff and should anticipate the problems that may trigger one. The RTO is one of the most demanding maneuvers for a flightcrew to perform, especially if conducted in a heavy aircraft at or near V_1, as occurred in this accident. These situations may require a pilot to exercise skill and to make instant decisions at the limits of his/her knowledge and training. Since it is impossible to predict, for instance, a possible tire failure on a heavy, high-speed takeoff, knowledge about various types of situations, when properly applied, can alleviate the need to rely entirely on skill. Obviously in any situation the more background information a pilot has, the faster and more accurate the decision-making process can be.

Training of pilots to respond with one procedure, cued solely by V_1 speed, for all RTO situations has been based on several principles. First, it may be preferable to keep an aircraft with a problem on the ground rather than to take it into the air. Second, there is the innate difficulty of evaluating anomalies and deciding on alternative actions while accelerating at high speed. Third, it is a well-documented training principle that training for a single response to any emergency strengthens the automatic, uniform, expeditious response of the entire flightcrew in a unified action. The Board understands this reasoning but believes that, given the statistics and the finding that more RTO's are caused by tire failures than engine failures, RTO procedures should be reviewed. Perhaps the decision to reject takeoff should be based on an increasing level of criticality as the aircraft approaches V_1. One consideration could be that when takeoff speeds are between 20 knots below V_1 and V_1, only an engine failure could cause the initiation of an RTO. Tire failures and other less serious anomalies would not automatically prompt an RTO. This would address a situation where tire problems manifest themselves just before or at V_1, compromising the aircraft's capability to stop within the remaining available runway. If the takeoff would be continued, the damaged tire system would neither be subjected to the full weight (without some aerodynamic lifting) of an aircraft loaded for takeoff nor to the stress of a high-speed, maximum-braking-effort RTO. It may be that the only high-speed tire failure that would require an RTO would be one that had caused major engine degradation. The Board feels that further study is required in this area to provide pilots with more background information to enhance their knowledge and decision-making capability and that such information could have enhanced the pilot's decisions in this accident.

Most RTO training for air carrier flightcrews occurs in flight simulators, and this training is limited by the capability of the simulator and by training requirements. Since statistics indicate that most RTO's result from tire failure, the Board believes that there is a need to realistically program a simulator model with these characteristics. This should include the effects of braking with a blown tire or tires; braking with part of the truck rolling on rims; the interactions of blown tires and antiskid braking; directional control problems; the braking effort required for maximum effectiveness; and the hazards associated with high-speed RTO's on frangible rims.

Once the pilot made the decision to reject the takeoff, he had two options remaining: maximum deceleration to stop the aircraft as soon as possible, or less than maximum deceleration. The pilot did react promptly to the tire failures and in accordance with ARC takeoff RTO procedures, with the possible exception of braking. The pilot stated that he intended to use light braking because of the runway length (which was 2,800 ft more runway than the minimum required by the balanced-field concept), directional control problems, and his concern with failure of additional tires. These factors led to the pilot's decision not to immediately stop the aircraft. The Board believes that the pilot's decision to allow the aircraft to roll out was based on his experience and on his perception and assessment of the situation. The Board does feel, however, that once an abort decision has been made, maximum braking should be applied immediately for the most efficient deceleration. Maximum braking should be held until the aircraft stops while also maintaining directional control. The reasons for this recommended procedure include the following:

(1) Possible puncture of wing fuel tanks is minimized.
(2) Wheel braking is most effective while tires are on the wheel rims.
(3) The risk of additional failure, including brakeline rupture, fuselage puncture, or rim failure, is minimized.
(4) Onboard personnel can evacuate sooner.
(5) Aircraft are built and certified to endure brake fires.

In this accident, if the pilot had elected to use maximum wheel braking to stop the aircraft as soon as possible, he might have realized significant antiskid braking capability on the dry runway surface, and directional control problems would have been minimized. The unique failure modes of this antiskid system do not allow a more definitive statement.

The Board concludes that a fresh look should be given to RTO procedures and training. In addition, all pilots should be made aware of accident/incident statistics involving RTO decisions versus completing the takeoff and of the necessity to use maximum deceleration in response to an RTO decision.

2.6 Nose Wheel Steering

The aircraft veered to the right immediately following the tire failures. The pilot stated that during the rollout he had been concerned with keeping the aircraft on the runway, using the nose wheel steering to control the aircraft track. He had felt that the nose wheel steering was having little effect and thought the nose wheel tires may have also blown out. An examination of the nose wheel tires indicated they had experienced low cornering forces with a wear pattern showing sideways scuffing, an indication of nose wheel steering ineffectiveness. The Board is concerned that all pilots should be aware that the rudder is most effective for directional control at high speeds and that nose wheel steering is most effective at low speeds.

Onboard witnesses stated that the pilot appeared to have difficulty maintaining directional control by using nose wheel steering during the early phase of the RTO. In addition, the aircraft commander stated that he was not holding the control yoke forward during the rollout. Although RTO procedures in the CV-990 manuals used by ARC pilots do not specifically state that the yoke be held forward during a RTO, they do specify that it be held forward during takeoff and immediately after the nose wheel is on the runway after landing to enhance directional control. Therefore it follows that the same procedures should apply for RTO's, and the Board believes that RTO procedures should include holding forward pressure on the yoke during rollout, consistent with the parallel requirements for directional control versus maximum braking effectiveness.

2.7 Operation of Antiskid Brake System

The CV-990 antiskid brake system has pressure control characteristics that pilots should be aware of when operating in a failed-tire mode. Hydro-Aire engineers stated that when nonuniform wheel speed conditions exist (such as failure of tires 3 and 4), maximum brake pedal deflection would result in one of three scenarios:

(1) Brake pressure is applied only to the fast wheels (nos. 3 and 4) promptly (1 to 2 sec) reducing the speed differential. Once the speed differ-

ential with the other main wheels is within 30 percent, the system returns to normal, fully modulated, individual-wheel-control antiskid braking.

(2) The wheel or wheels without tires fully lock and remain locked, flat spotting the rim or rims.

(3) The wheel or wheels without tires spin down, generate a locked-wheel release, spin back up to freewheeling speed, and then repeat this cycle. In this scenario the six normal main wheel brakes remain fully released.

Although, in this accident it is most likely that effective braking would have been realized, it cannot be known since the pilot elected to use minimum braking. The Board feels that additional study is required in this area to ensure that pilots have a good understanding of antiskid brake system anomalies caused by failed tires.

2.8 Cockpit Resource Management

Another training program that could have enhanced the pilot's decision-making in recognizing and responding to the hazard in this accident scenario is cockpit resource management (CRM). CRM refers to the utilization of all available resources, whether it be information, equipment, or people, to achieve safe and efficient flight operations. It includes elements such as delegation of tasks, assessment of problems, use of available data, communication, and effective flightcrew coordination.

More effective communications between the cockpit and the aircraft cabin, tower, or ground could have provided critical information to the pilot at an earlier time. In particular, during the takeoff roll and before the first blowout some cabin occupants had noted several abnormalities including a "black object" flying over the wing and deformation of tire 3. Communication with tower or ground during the takeoff roll could have alerted the pilot to the seriousness of the problem. The U.S. Air Force air traffic control waivered procedure of switching NASA 712 to departure control frequency before starting the takeoff roll was not in concert with the accepted ATC practice of having a transport aircraft switch to departure control after takeoff. As a result of this frequency change and the flightcrew not monitoring the control tower frequency, calls from the tower controller that NASA 712 was on fire were not heard by the pilot. Had the pilot known that the aircraft was on fire, the Board feels that his actions might have been different, including stopping the aircraft more quickly. The Board recommends that military air traffic controllers comply with the procedures regarding radio frequency changes as stated in FAA Air Traffic Control Manual 7110.65. In addition, NASA flightcrews should monitor the controlling agency frequency during takeoff.

Because the critical nature and extent of the operational hazard was not immediately obvious to the flightcrew, cockpit resource management training could have enhanced the pilot's use of all available resources as well as the other crewmembers' coordination in actively supporting the pilot in assessing the condition of the aircraft and in implementing a safe and successful RTO.

In recent years CRM has been demonstrated statistically to be significant in critical operating situations. For this reason many airlines have incorporated the principles of flight deck resource management into their training programs. The USAF Military Airlift Command (MAC) has stated that crew coordination and cockpit leadership are "two of the hottest subjects in the command today." In 1979, the FAA issued an Air Carrier Operations Bulletin instructing all principal operations inspectors to urge their assigned carriers to include CRM training in flightcrew programs.

The Board feels that cockpit resource management could have helped to optimize flightcrew performance during this accident sequence. It recommends that NASA incorporate CRM training into their programs for multicrewmember aircraft.

2.9 CFR Personnel Response

The current CFR notification network procedure, which requires information regarding the nature of the emergency to be acquired and recorded before the CFR vehicles are dispatched, is designed to respond to an airborne emergency with prenotification. In general, alarm room operator procedures are based on a structured, announced fire scenario, not a dynamic unannounced emergency. Operators are currently trained to gather all information, to alert CFR personnel, and then to dispatch the equipment. Critical time could be saved if the alert could take place concurrently with primary crash notification when an accident has occurred without prenotification, as was the case with the CV-990. The CFR response time could have been shortened by about 1 minute and 22 seconds had the alarm room operator alerted CFR personnel and dispatched the equipment immediately after he had been notified of the emergency by the tower, at 1810:28.

Response time could have been further shortened by at least 15 seconds had the alert been given when the operator first became aware of the emergency, that is, after the first statement of the tower notification. The Board concludes that alarm room operator alerting of CFR personnel should take place as soon as sufficient information is available to confirm that CFR response is required to an emergency action. Further information can be gathered and transmitted after the initial alerting action while CFR response is under way.

The delay in the fire alarm room communications center could have been avoided. This delay did not play a significant role in the final outcome because of the fully involved running-fuel fire. However, if the aircraft had not been evacuated effectively, it could have been a significant factor. The Board believes that this delay could have been prevented through procedural changes to facilitate the alarm room operator's notification of the firemen.

During this emergency event there was a relief operator in the alarm room. Although he was trained and qualified for that position, his primary duty was as the designated driver of the P-15 truck, and he routinely had spent only a few minutes at a time in the alarm room as a relief operator. Also, although he had received instructions on procedures, he had not had hands-on training in alarm room activities and had never handled an actual emergency. The Board believes that practicing several different alarm room scenarios in a hands-on fashion by designated relief operators would enhance response effectiveness.

Since the relief operator was also the driver of the P-15 truck, this major firefighting vehicle, which contained AFFF, was delayed in responding to the accident. The Board feels that firefighters assigned to critical response positions should not be used as relief operators.

2.10 Fire Control

The AFFF used on this fire was a 3 percent concentrate and met Military Specification F-243-85C. Information gathered during the investigation revealed that some civilian airports use AFFF that meets UL Standard 162. Testing at the FAA Technical Center's Fire Safety Branch indicated that only a small percentage of the test samples of all types of firefighting agents meeting UL Standard 162 could also meet the test requirements of Military Specification F-243-85C. The requirements for Military Specification F-243-85C set the highest standards for AFFF agents. Investigation also revealed that there is no national standard for AFFF agents.

Because of the limitations in firefighting techniques, control, and suppression there was the possibility of a catastrophe in this accident had the 19 occupants not evacuated as quickly and effectively as they did. The Board is concerned about the safety of occupants in similiar accident scenarios and believes that greater emphasis should be placed on fire control, suppression, and containment techniques. In addition, NASA should consider the use of more fire-retardant materials and structural and cabin fire protection systems in its aircraft.

3.0 CONCLUSIONS

3.1 Findings

1. The crewmembers were properly certified and qualified for the flight in accordance with NASA Ames Research Center (ARC) policies.

2. The aircraft commander was occupying the right seat and performing copilot duties for this flight. The assigned pilot was seated in the left seat making the takeoff.

3. The aircraft was operated as a public aircraft and was maintained in accordance with Convair 990 maintenance manuals and ARC procedures. Modifications to the aircraft had been made and approved in accordance with ARC airworthiness requirements.

4. The active runway for landing and takeoff at March Air Force Base (AFB), runway 32, is 300 feet wide by 13,300 feet long.

5. The runway was dry and the outside temperature was 85 °F.

6. The taxi distance from NASA 712's parked position on the ramp to the departure end of runway 32 was 2.4 miles. Average taxi speed was about 25 knots.

7. The flightcrew completed the before-takeoff checklist, established takeoff thrust, and began the takeoff at approximately 1,000 feet from the takeoff end of runway 32.

8. The March AFB control tower requested that NASA 712 switch to departure control frequency before takeoff.

9. The cockpit crew was not monitoring March AFB control tower or emergency frequencies during the takeoff.

10. The pilot, after hearing two rapid explosive bangs and associating them with a blown tire, rejected the takeoff. He reduced thrust to idle, deployed the spoilers, and selected reverse thrust on all engines. Reverse thrust was applied about 14 seconds after the pilot heard the first explosive bang.

11. The pilot stated that he decided to use light braking in view of the remaining runway, the suspected blown tire or tires, and his concern with keeping the aircraft aligned on the centerline.

12. The procedures outlined in the ARC flight manuals available to the pilot do not directly address rejected takeoffs with blown tires but do state that braking should be used in rejecting a takeoff.

13. The aircraft commander (copilot) did not hold the control yoke forward during the rollout. The resulting light cornering forces on the nose wheel reduced nose wheel steering effectiveness.

14. The main gear tires had been properly inflated and the brake systems were normal before the takeoff was rejected.

15. The first tire anomaly was failure of the casing on tire 3. The first pieces of casing were found on the runway at about 1,400 feet. The carcass blew at 4,138 feet, immediately after tire 4 failed. Tire 4 failed at 4,125 feet from overloading and heating.

16. A third tire failed at the no. 8 position at 6,190 feet, 2,065 feet after tire 4 failed. Tire 8 failed from overloading or damage from wheel debris.

17. A fourth tire failed at the no. 7 position at 7,300 feet, 3,175 feet after tire 4 failed, also from overloading or damage from wheel debris.

18. Tires 3, 4, and 7 were 12 years old. Tire 8 was 9 years old. Tires 3 and 7 were 24-ply rated and tires 4 and 8 were 22-ply rated. Tire 3 was on its sixth retread, tires 4 and 7 on their fourth retread, and tire 8 on its second retread.

19. A right-wing fuel tank was penetrated, most likely between 6,000 and 7,000 feet down the runway by an unknown object. Outside witnesses stated that they saw fire on the aircraft at about 7,000 feet, coinciding with the application of reverse thrust. The first signs of fire on the runway were at 11,950 feet.

20. The aircraft was stopped at 12,660 feet, 640 feet from the end of the runway and about 30 feet to the right of centerline.

21. The forward and aft left-side aircraft exits were opened, and the slides were used by all occupants to successfully evacuate the aircraft in a timely manner.

22. The control tower operator completed notification to the fire department's alarm room operator (a relief operator was on duty) on the primary crash network at 1810:28. The primary crash network was secured at 1810:51, and the alarm room operator responded to the secondary crash network at 1810:55. He secured the secondary crash network telephone and simultaneously alerted crash/fire/rescue (CFR) personnel in the fire station at 1811:50.

23. The relief alarm room operator had neither experience in an emergency situation nor hands-on training. His primary duty was as driver of a major CFR vehicle (a P-15 truck).

24. There was an avoidable delay of 1 minute and 22 seconds in dispatching fire equipment.

25. The first CFR vehicle had traversed the 1.6 miles to the accident site and was engaged in firefighting at 1814:24, 3 minutes and 56 seconds after notification.

26. During the firefighting effort, 1,915 gallons of aqueous film-forming foam (AFFF) and 59,000 gallons of water were expended. The fire abated as the right-wing fuel supply was exhausted.

27. Aircraft accident/incident statistics indicate that more rejected takeoffs are due to tire failures than to engine failures.

28. The Board along with Hydro-Aire engineers looked at the operation of the antiskid brake system even though it was not determined to be a factor in this accident. The CV-990 antiskid brake system has pressure control characteristics that pilots should be aware of when braking with failed tires.

3.2 Probable Cause

The NASA Aircraft Accident Investigation Board determined that the probable cause of the accident was the nearly simultaneous failure of the two front tires on the right main landing gear at a critical time during the takeoff roll. These failures resulted in the pilot's decision to reject the takeoff. Contributing to the severity of the accident was an intense fire fed by leakage from the puncture of a right-wing fuel tank forward of the right main gear; the puncture occurred during the intentional extended rollout of the aircraft.

4.0 SAFETY RECOMMENDATIONS

As a result of its investigation of the Convair 990, NASA 712, accident of July 17, 1985, and a review of pertinent background documents and reports (appendix D), the NASA Aircraft Accident Investigation Board makes the following recommendations.

4.1 Federal Aviation Administration

1. Require that flight manuals for large multiengine aircraft provide information on procedures for takeoff emergencies other than engine failure. This information should include guidance for continuing versus rejecting takeoff when an aircraft with all engines operating normally develops anomalies at high speed before reaching V_1, the speed at which a takeoff decision must be made. Factors such as directional control, tire failures, wheel rim failures, antiskid braking characteristics, brake line vulnerability, and fuel tank and structural vulnerability to penetration could be considered. Hazard analyses and risk assessments for various scenarios could be discussed to provide background information for flightcrews to enhance their decision-making during takeoff emergencies.

2. Require that flight manuals for large aircraft specify rejected-takeoff procedures involving tire failures and provide guidance on stopping procedures. Control yoke management procedures to enhance directional control, similar to guidance provided for takeoffs and landings, should be addressed.

3. Sponsor a joint research effort with other appropriate Government agencies to improve firefighting capabilities for running-fuel "three dimensional" fires.

4. Continue to research the characteristics of various aviation firefighting agents in order to identify the most effective agents and to establish a national standard for aviation firefighting agents.

5. Provide additional emphasis to enhance compliance with the design criteria for aircraft structures and systems so as to locate fuel tank and other critical inspection plates on surface areas that are not vulnerable to debris from failed tires, wheels, and brake assemblies.

6. Require that manufacturers review the antiskid braking system characteristics of large multiengine aircraft, with particular attention to multiple tire or wheel failures and their effect on system operation and overall braking effectiveness. Each manufacturer should provide operators with an analysis of the results of such reviews and suggested procedures for pilot response to tire/wheel failures.

7. Review and amend, as necessary, the criteria established for the number of tire retreads permitted on a single carcass and for the removal of tires from service due to age or number of cycles.

8. Encourage greater use of stronger wheels with roll-on-rim capability for transport category aircraft certified since 1979.

9. Review and modify current flightcrew requirements to include timely training programs that adequately address tire, wheel, and brake problems during takeoff. Motion-based simulators used in the program should have models that provide realistic training in the recognition and handling of such problems.

10. Review and amend, as necessary, the design criteria for large aircraft wheels and tires to preclude sympathetic tire failures occurring after an initial single tire failure. Considerations should include heavyweight takeoffs and landings.

11. Alert CV-990 operators of potential antiskid failure modes that can result from loss of two tires on the same axle. Determine if any antiskid system with similar logic is operable on other U.S. aircraft and issue an alert.

4.2 Department of Defense

1. Review and modify air traffic control procedures so that all military air traffic control towers comply with the provisions of Chapter 3, Section 9, Departure Control Instructions, FAA Air Traffic Control Manual 7110.65.

2. Review current practice to ensure that crash/fire/rescue procedures for alarm room operators include immediate alerting of firefighting personnel in response to an unannounced emergency.

3. Require that firefighters assigned to critical positions be precluded from relief operator assignment.

4. Ensure that all crash/fire/rescue alarm room operators receive hands-on training.

4.3 NASA Headquarters

1. Sponsor a study with industry to assess the hazards from blown tires on heavy aircraft. The study should consider the following:

   a. Susceptibility of aircraft structure and systems to damage
   b. Maximum braking versus limited braking
   c. Anomalies of antiskid brake systems
   d. Continuing versus rejecting takeoff

2. Evaluate and develop the requirement for flightcrews of large NASA aircraft to receive training in FAA Phase II or Phase III simulators capable of presenting realistic failed-tire models.

3. Evaluate and establish a requirement for incorporation of cockpit resource management training into NASA flight training programs for multicrew-member aircraft.

4. Establish guidelines requiring that only new tires or retreads of NASA tires be used on NASA aircraft.

5. Develop NASA criteria for the number of tire retreads permitted on a single carcass and for the removal of tires from service because of age or number of cycles.

6. Establish guidelines requiring that all occupants of NASA aircraft on research missions wear flight suits made from appropriate fire-retardant materials.

7. Establish a policy to ensure that original designs and manufacturers' blueprints, drawings, etc., of unique equipment onboard NASA aircraft during research missions be retained at appropriate ground facilities. The only existing copies of such materials should not be carried onboard NASA aircraft.

4.4 NASA Aircraft Operations Managers

1. Establish procedures for rejected takeoffs that parallel accepted air carrier industry practices, with emphasis on the use of maximum wheel braking and control yoke management.

2. Review the practicality of using wheels with roll-on-rim capability on appropriate NASA aircraft and, if feasible, implement their use.

3. Review the current status of, and need for, structural and cabin fire protection systems on NASA aircraft and, where appropriate, update those systems to incorporate modern detection and suppression devices.

4. Develop guidelines to minimize the use of tires with different ply ratings or tires produced by different manufacturers on the same axle where differences in characteristics between such tires can affect tire loading under normal operating conditions (see National Transportation Safety Board Recommendation A-78-71, addressed to the Federal Aviation Administration, dated 9/6/78).

5. Ensure that copies of pertinent aircraft operational and maintenance logs are retained at appropriate ground facilities.

6. Ensure that preflight inspection records contain the measured tire pressures.

7. Require that all NASA flightcrews monitor the controlling facility radio frequency or appropriate emergency frequency during takeoff.

APPENDIX A

FLIGHTCREW INFORMATION

Aircraft Commander Gordon H. Hardy

Mr. Hardy, age 52 at the time of the accident, is assigned to the Research Aircraft Operations Division, NASA Ames Research Center, as a research pilot. He holds airline transport pilot certificate 1323097, dated 1/14/83. He has a valid first-class medical certificate, issued 11/02/84, with the limitation that the holder shall wear corrective lenses for distant vision and possess corrective lenses for near vision while flying.

Mr. Hardy completed a 40-hour CV-990 ground school on 1/10/83 and aircraft commander flight training on 1/14/83. His most recent CV-990 flight check had been on 5/29/85.

Mr. Hardy had about 7,816 flying hours at the time of the accident, including 680 CV-990 flying hours with 380 hours as first pilot. He had flown 80 hours in the previous 30 days, 32 hours as first pilot and 2 hours in the CV-990.

Pilot Eugene H. Call

Mr. Call, age 45 at the time of the accident, is assigned to the Research Aircraft Operations Division, NASA Ames Research Center, as a support pilot. He holds airline transport pilot certificate 1521931, dated 4/5/85. He has a valid first-class medical certificate, issued 11/30/84, with no limitations.

Mr. Call completed a 40-hour CV-990 ground school on 8/4/83 and copilot flight training on 1/26/84. His most recent CV-990 flight check had been on 5/29/85.

Mr. Call had about 7,850 flying hours at the time of the accident, including 100 CV-990 flying hours with 23 hours as first pilot. He had flown 76 hours in the previous 30 days, 44 hours as first pilot and 11 hours in the CV-990.

Flight Engineer Frank P. Kosik

Mr. Kosik, age 39 at the time of the accident, is assigned to the Research Aircraft Operation Division, NASA Ames Research Center, as a flight engineer. He holds a valid first-class medical certificate issued 8/8/85, with no limitations.

Mr. Kosik completed a 40-hour CV-990 initial ground school in 2/76 and flight engineer flight training in 3/76. He had about 4,000 flying hours at the time of the accident.

Navigator Eugene A. Moniz

Mr. Moniz is an employee of Northrop Services at NASA Ames Research Center and is assigned duties as a navigator.

APPENDIX B

AIRCRAFT INFORMATION

Convair CV-990, serial no. N712NA (Commercial 30-10-37) had been manufactured on 6/27/61. NASA Ames Research Center acquired the aircraft on 12/10/73, when it had 8,199 flight hours. It was registered by the FAA and maintained as a public aircraft according to the manufacturer's procedures and recommendations. At the time of the accident the aircraft had accumulated 12,104 flight hours and logged 4,974 landings. The last major inspection (250 hours) and the 50-hour check had been done 27 flight hours before the accident, and the annual inspection had been completed in 2/85.

Maintenance Records Reviewed

(1) Convair Model 30 Maintenance Manuals
(2) Convair Model 30 Structural Repair Manual
(3) Convair Model 30 Operations Manual
(4) Preflight Form RSI43
(5) Postflight Form FOI45
(6) Inspection and Modification Discrepancies Form OAW-18
(7) Form 781-OA-3
(8) Form 781-OA-4
(9) Aircraft Delayed Discrepancy and Special Inspection Record, FOI3
(10) Removal Record Form, 781-OA-10
(11) Aircraft Inspection and Operating Time Data Record, 781-OA-6
(12) DD Form 365B, Weight and Balance

Engines: General Electric, CJ805-23B

Engine	Serial no.	Date of installation	Time of installation, hours	Total time, hours
1	175-137	1/09/85	219	382
2	414-182	7/02/85	3432	3455
3	414-129	8/08/83	338	1140
4	414-189	3/10/85	4836	4994

Nose Tires

Position	Serial no.	Date of installation	Number of landings
Left	0544	04/15/85	18
Right	0565	04/15/85	18

Brakes

Position	Serial no.	Date of manufacture	Date of installation
1	B0394	(a)	01/29/85
2	(a)	(a)	(a)
3	B0736	12/14/61	08/08/84
4	B0299	04/04/61	10/01/84
5	B0412	(a)	10/01/84
6	B0117	(a)	05/30/85
7	B0733	12/14/61	10/01/84
8	B0726	12/14/61	01/04/85

[a]Unknown.

Service History of Right Main Landing Gear Tires

Tire 3, serial no. 335MV443, was 24-ply rated and had been manufactured by Goodyear Tire and Rubber Company in 9/73. The tire had been retreaded six times, the last by Thompson Aircraft Tire Corporation in 6/81. The wheel and tire assembly had been installed on the aircraft on 8/8/84. The tire had experienced 140 landings since its last retread, and approximately 2/32 inch of tread groove depth remained.

Tire 4, serial no. 33NJ348, was 22-ply rated and had also been manufactured by Goodyear. One digit was missing from the serial number identifying the date of manufacture. The fourth retread had been by Thompson in 12/84; so the tire was probably manufactured in 1973 rather than 1983. The wheel and tire assembly had been installed on the aircraft on 3/28/85. The tire had experienced 45 landings since its last retread, and approximately 8/32 inch of tread groove depth remained.

Tire 7, serial no. 342NJ1267, was 24-ply rated and had been manufactured by Goodyear in 10/73. The fourth retread had been by Thompson in 2/84. The wheel and tire assembly had been installed on the aircraft on 8/22/84. The tire had experienced 131 landings since its last retread, and approximately 3/32 inch of tread groove depth remained.

Tire 8, serial no. 63000171, was 22-ply rated and had been manufactured by Goodrich Tire and Rubber Company in 10/76. The second retread had been by Thompson in 3/84. The wheel and tire assembly had been installed on the aircraft on 3/28/85. The tire had 45 landings since its last retread, and 9/32 inch of tread groove depth remained.

It is NASA ARC policy to change tires when tread groove is not visible on any part of the tire, when the tread has been cut to the cord, or when there is a cut in the sidewall.

APPENDIX C

COCKPIT VOICE RECORDER TRANSCRIPT

Symbols

CAM-1 Pilot, left cockpit seat

CAM-2 Aircraft commander, right cockpit seat

CAM-3 Flight engineer

Tower March AFB control tower

(*) Nonpertinent word or phrase

(?) Questionable source or word

Transcript

Time, min:sec	Source	Cockpit conversation	Source	Communication
	712	Before-taxi checklist completed.		
			Tower	Cleared to taxi.
	712	Pretakeoff checklist completed.		
		STAB setting 4.2.		
		V_1 - 151.		
		V_R - 154.		
		80-knot check.		
	712	Abort briefing.		
	CAM-1	If we've got to abort, we've got plenty of runway. Don't forget the spoilers. Remind me to get the spoilers. Stop the (*) straight ahead. If we get airborne, I'll fly the airplane with the right side up. Any procedures, I'll explain. Stay VFR. Take care of whatever it says in the book.		
	CAM-3	Before-takeoff checklist complete. Holding on final item.		
			Tower	NASA 712 taxi into position and hold.
1806:29	CAM-2	712 position and hold.		
1806:33	CAM-3	Final item antiskid on.		
1806:35	CAM-3	Transponder.		
	CAM-2	Transponder on.		
	CAM-3	Running lights.		
1806:40	CAM-2	Running lights on.		
	CAM-3	Very end.		
1806:43	CAM-3	Final item complete.		
1806:47	CAM-3	Do you want me to help you set the power?		

Time, min:sec	Source	Cockpit conversation	Source	Communication
1807:05	CAM-2	Just relax.		
	CAM-1	Relaxed.		
1807:13	CAM-1(?)	This is a heavyweight takeoff. You better get psyched up a little.		
1807:16	CAM-3	Yeh, we're using 10,000 ft of runway. Think I'm kidding, huh?		
1807:18	CAM-1	We're gonna get rolling on this (*)		
1807:22		(Laughter)		
1807:24	CAM-2	Keep relaxed.		
1807:27	CAM-2	Is that an airplane down there? Is it a hill or something? Look at that.		
1807:32	CAM-3	That's an ACM (?)		
1807:43	CAM-1	This may be my..... (*)		
1807:51	CAM-3	I'll tell you what, you better not crash because this whole cockpit is going to be full of ice cream.		
1807:55	CAM-1	It'll help douse the fire.		
1808:01	CAM-1	If we get any real (*), just start dumping the gas.		
1808:04	CAM-3	Yeh, don't even worry about turning back. Just give me the word and it'll be done.		
1808:09	CAM-3	In fact, I'm gonna...		
1808:10			Tower	NASA 712, Tower, traffic is a C-135 exiting the runway at departure end. Wind three zero zero at five. Change to departure; cleared for takeoff.
1808:20			CAM-2	712 cleared for takeoff.
1808:20	CAM-3	Want me to set 127.35 with it?		
1808:21		(Sound of engine spoolup)		
1808:23	(?)	Ready?		
1808:40		(Engine sound stabilizes)		
1808:54	CAM-3(?)	I've set the power.		
1808:57	CAM-3	There's 80 knots.		

Time, min:sec	Source	Cockpit Conversation	Source	Communication
1809:04	CAM-3(?)	They're all setting on 187.		
1809:14		(Two rapid explosive sounds)		
1809:16	CAM-2 CAM-3	Abort. Blown tire. (simultaneous)		
1809:18		(Sound of engine spooldown)		
1809:19	CAM-2	Tire.		
1809:20	CAM-1	I'm gonna stay off the brakes. They'll have little effect.		
1809:24		(Explosive sound)		
1809:26	CAM-3	Blew another one.		
1809:28		(Sound of engine spoolup - reversers)		
1809:29		(Explosive sound)		
1809:33			CAM-2	NASA 712 is aborting.
1809:43	CAM-3	3000 ft		
1809:50		(Sound of engine spooldown)		
1809:57	CAM-2	Well, how about that?		
1810:01	CAM-2	We kept them apples...		
1810:04	CAM-1	I think it was the left side.		
1810:07	CAM-2	I think we blew two.		
1810:08	CAM-3	Yeh, oh yeh...		
1810:10			NASA ground	Casey, you're on fire.
1810:15	Mission Manager	Fire on the right side.		
1810:17	CAM-2	We have a fire on the right side.		
1810:21	CAM-1	...We'll just stop...Let's just stop right here...		
1810:24	CAM-2	Let's shut'em down.		
1810:24			CAM-2	NASA 712 unable to taxi.
1810:30			Depart-ture Control	NASA 712, you have Departure Control. Report airborne please.
1810:34		(Sound of engine shutdown)		
1810:39		(End of recording)		

APPENDIX D

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PLACED IN ACCIDENT INVESTIGATION REPORT DOCKET[6]

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3. John B. Graybeal, Informatics Computer Technician	15
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July 17, 1985
Facts and Analysis

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16. Abstract

On July 17, 1985, at 1810 P.d.t., NASA 712, a Convair 990 aircraft, was destroyed by fire at March Air Force Base, California. The fire started during the rollout after the pilot rejected the takeoff on runway 32. The rejected takeoff was initiated during the takeoff roll because of blown tires on the right main landing gear. During the rollout, fragments of either the blown tires or the wheel/brake assemblies penetrated a right-wing fuel tank forward of the right main landing gear. Leaking fuel ignited while the aircraft was rolling, and fire engulfed the right wing and the fuselage after the aircraft was stopped on the runway. The 4-man flightcrew and the 15 scientists and technicians seated in the cabin evacuated the aircraft without serious injury. The fire was not extinguished by crash/fire/rescue efforts and the aircraft was destroyed.

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